THE IMPACTS OF ANTHROPOGENIC ACTIVITIES ON GROUNDWATER POLLUTION IN DERNA REGION, LIBYA

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

09May 2013 JUMMA ARHOUMA JUMMA ELGALI
P54740

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ABSTRACT

In Libya, groundwater is the main source of fresh water. The lack of water reduces the ability to maintain quality, especially if there are multiple sources of pollution. The study aims to provide information on the spatial characteristics of groundwater quality in Derna Region, northeastern part of Libya. Specifically, the study focuses on identifying the key factors that lead to groundwater contamination, its suitability for human consumption and the spatial distribution of groundwater contamination. Thirty-one water samples were collected and analyzed namely PH, EC, TDS, T.H, Ca++, Mg++, Fe, NH4, C1, NO2, PO4 and E. coli. Chi square, one-way ANOVA and regression analyses were employed to analyze the statistical data gathered from the stratified relative sampling carried out within the study area. The Geographical Information system (GIS) technique was employed as a tool to produce maps for the spatial distribution of groundwater quality. Pollution status was calculated and compared with Water Quality Index (WQI) as recognized by the Water General Authority in Libya. The results showed that the sewage overflow, waste accumulation, pesticides and fertilizer were the most sources of groundwater pollution based on the result of the analysis, where 67% (n= 450) of the population confirmed that there is an overflow of sewage, and 65% (n = 450) have noticed waste accumulation. On the other hand, the study has shown that more than two third (66%) of farmers have used pesticides and fertilizers. Chi square has shown an association between the mentioned sources and water quality changes. One-way ANOVA indicated that there is a difference in average of *E. coli* counts between the region's sections. Al-Belad had the highest average of E. coli count (50counts/100 cm^3) mainly due to highest population density with worn out sewer system. The ANOVA analysis indicated that (P. Value = 0.814). TDS, T.H, Cl and E. coli have exceeded the permissible level in several samples, and their values were 8000 mg/l, 1700 mg/l, 1140 mg/l and 100 germs per 100 cm^3, respectively. GIS zonation maps of groundwater quality parameters indicated that most of the high values of parameters are concentrated in the northern and northwestern parts of the region, where there is an increase in population density and urban development. The WQI values of groundwater ranged from 20.63 to 100 %, and revealed that 14.3% were absolutely clean water (Class Ia), 64.3%were slightly polluted water (Class Ib) and 21.4% very polluted water (Class IIIa&b), as referred to the water quality index in Libya. The derived Multivariate Linear Regression (MLR) of determination (R^2) is 0.914 which means that 91% of variance in the dependent variable (WQI) are explained by the set of predictors (WQ parameters). MLR showed that the WQI was found to be inversely correlated with most of the water-quality parameters (77.8%) which indicates an increase in water quality when the concentration of the water parameters decline.

ABSTRAK

Di Libya, air bawah tanah merupakan sumber utama bekalan air. Kekurangan sumber air akan mengurangkan keupayaan dalam stabilkan kualiti, terutama apabila terdapat beberapa sumber pencemaran. Kajian ini bertujuan untuk memberikan maklumat mengenai ruang ciri kualiti air bawah tanah di Wilayah Derna, bahagian timur laut Libya. Secara khususnya, kajian ini memberi tumpuan untuk mengenal pasti faktor-faktor utama yang membawa kepada pencemaran air bawah tanah, membincangkan kesesuaiannya untuk kegunaan manusia dan taburan pencemaran air bawah tanah. Borang soal selidik telah dibuat, dan 31 sampel air telah dikumpulkan dan parameter yang adalah seperti PH, EC, TDS, TH, Ca + +, Mg + +, Fe, NH4, C1, NO2, PO4 dan *E.coli*. *Chi square*, ANOVA sehala dan analisis regresi telah digunakan untuk menganalisis data statistik yang dikumpulkan dari pensampelan berstrata relatif yang dijalankan di dalam kawasan kajian. Teknik Sistem Maklumat Geografi GIS telah digunakan sebagai model untuk menghasilkan peta taburan kualiti air bawah tanah.Status pencemaran dikira dan dibandingkan dengan Indeks Kualiti Air (WQI) seperti yang diiktiraf oleh Pihak Berkuasa Air Besar di Libya. Hasil kajian menunjukkan bahawa limpahan kumbahan, pengumpulan sisa racun perosak dan baja sumber-sumber pencemaran air bawah tanah berdasarkan hasil analisis soal selidik ini, di mana 67 % (n = 450) daripada jumlah penduduk mengesahkan bahawa terdapat limpahan kumbahan, dan 65 % (n = 450) daripada mereka mendapati sisa terkumpul. Sebaliknya, kajian telah menunjukkan bahawa lebih daripada dua pertiga (2 / 3) petani telah menggunakan racun serangga dan baja. Chi square telah menunjukkan kaitan dua faktor di atas dengan perubahan kualiti air. ANOVA sehala menunjukkan bahawa terdapat perbezaan dalam purata jumlah *E.coli* antara bahagian-bahagian di rantau ini. Di Al-Belad yang mempunyai purata tertinggi jumlah *E.coli* (50/100 cm3) disebabkan oleh kepadatan penduduk tertinggi dengan yang dipakai sistem pembetung. Analisis ANOVA menunjukkan (nilai P = 0.814). TDS, TH, Cl dan *E.coli* telah melebihi jumlah yang dibenarkan dalam beberapa sampel iaitu 8000 mg / l, 1700 mg / l, 1140 mg / l dan 100 kuman bagi setiap 100 cm^3, masing-masing. Peta penzonan GIS parameter kualiti air menunjukkan kepada sebahagian besar daripada nilai-nilai parameter yang tinggi tertumpu di bahagian utara dan barat laut rantau ini, di mana peningkatan kepadatan penduduk dan pembandaran. Nilai WQI air bawah tanah antara 20,63-100, dan mendedahkan bahawa 14.3% adalah air bersih (kelas Ia), 64.3% adalah air sederhana tercemar(kelas Ib) dan 21.4% air yang sangat tercemar(kelas IIIa&b), sebagai merujuk kepada indeks kualiti air di Libya. Daripada keputusan Multivarian Regresi Linear (MLR) penentuan (R^2) adalah 0.914 yang bermaksud bahawa 91% daripada variasi dalam pembolehubah bersandar (WQI) yang dijelaskan oleh set ramalan (parameter WQ). MLR menunjukkan bahawa WQI didapati songsang yang berkait rapat dengan kebanyakan parameter kualiti air (77.8% daripada mereka) yang menunjukkan untuk meningkatkan kualiti air apabila kepekatan parameter air menurun.

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LIST OF ABBREVIATIONS

TDS	Total Dissolved Solids
TH	Total Hardness
pH	Measure Of The Acidity Or Alkalinity Of A Solution
EC	Electrical Conductivity
Ca++	Calcium
Mg++	Magnesium
Fe	Iron
NH_3	Ammonia
Cl	Chloride
NO_2	Nitrite
PO_4	Phosphate
GIS	Geographic Information System
WQI	Water Quality Index
WHO	World Health Organization
GWA	General Water Authority
GWC	General Water Company
ppm	Part per million
IDW	Inverse Distance Weighted
MENA	Middle East and North Africa
IWRM	Integrated Water Resources Management
Mg/L	Milligram per Liter
EPA	Environmental Protection Agency

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Since the appearance of human on the earth's surface, all his concern had been to protect himself from the dangers of environmental factors, the satisfaction of his multiple needs and increase well-being. Over time humans began to develop machinery and equipment; to take advantage of the resources of nature, and to protect the environment from the anthropogenic impact (Abu Raya 1999). Undoubtedly, agriculture, urban and industrial environments are artificial environments created by the human capacity to develop things as a result of the need for life activities. However, damages to this artificial capacity are equivalent to the desired benefits, and sometimes these damages are more than the benefits required. Environmental pollution occurs due to the introduction of these harmful results. Pollution is considered as one of the most important environmental problems facing the contemporary world, in both developed and developing countries. Progress in the development of industry and transportation and high population densities has led to deterioration and disruption of the environment causing varying pollution impacts (Nofal 1991). So, contamination is the issue of today; whereas the effects on human health and the environment are issues of tomorrow, couples with the effects on natural resources. Thereby, the interest in environmental issues, is not a luxury limited to the maintenance of purity and beauty of nature only, but it is related to human survival, health and production of resources, as well as related to the responsibilities towards future generations (Al-Mabrouk 2003).

Water is one of the most important resources bestowed by Almighty Allah for all humans, so it is assumed that humans must give a great interest and appreciation to this vital resource, and therefore should seek to maintain and preserve its purity. However, that the people in all parts of the world have shown a kind of neglect towards the water, making the future of humans and other organisms at risk unless improvements are made (Suleiman 1992). In Libya, groundwater is the main source of fresh water, providing a vital supplement to surface water sources. Groundwater availability and quality are vulnerable both to climate change and over-abstraction, and in regions where the water table has lowered (Elaswed et al. No date). The lack of water reduces the ability to maintain quality, especially if there are multiple sources of pollution. There is almost no surface water or groundwater source without pollution, and the natural pollution does not cause many risks because its causes were not in fact only part of the ecosystem. Serious pollution of water sources started emerging at the beginning of the spread of human activities on Earth (Sharaf 2000).

One of the most critical environmental problems that impede sustainable development in developing countries located in arid and semi-arid regions, is the lack of renewable water sources. In these regions, groundwater is the most important natural resource used for several purposes. Therefore, groundwater can optimally be utilized and sustained only when the quantity and quality is duly assessed. Human activities and geological characteristics can cause groundwater pollution, and thence, evaluation of groundwater quality is an important process for suitable groundwater (El-Hames et al. 2010).

The availability of water quality and quantity is necessary for the very existence of humans, animals and plants. Although, water is indispensable and plays a pivotal role in our lives, it is one of the most abused natural resources. Lack of awareness and use of inefficient methods lead to more than 50% of water wastage in the domestic, agricultural and industrial sectors. Acute pollution of water has rendered much of the available water unsafe for most of human consumption (Tandel et al. No date).

In fact there is no one specific definition of water pollution. However, (Sharaf 2000) defines it as “any damage to the water quality in reducing its fitness for specific purposes”. Accordingly, even when water is polluted, it does not prevent the usage for other purposes.

Since groundwater has a geographical context, Geographical Information System (GIS) can be a powerful and effective tool which can be applied for developing solutions for water resources problems, assessing water quality and, determining water quantity, and managing water resources (Hamad 2008), as well as for storing, analyzing, investigating groundwater quality information and displaying the spatial distribution of data. GIS is an important tool for efficient management of groundwater resources, and it helps to prepare a scientific database of water resources. Geographical Information System has been put to effective use in many previous groundwater studies and found to be extremely successful (Venkateswara et al. 2009). The most useful tools among GIS in the field of groundwater resource investigations are the quantitative and qualitative methods for spatial data analysis (Hamad 2008). Water quality index is an indicator revealing the composite influence of a number of water quality parameters which are significant for specific beneficial uses (Nair 2006).

Because of the rapid growth of population, urbanization and industrialization, there is an increasing pressure on land, water and the environment. Concentration of the population density in urban areas has led to the increase of buildings, roads, vehicles, and factories. These human activities result in several effects, including water waste and storm drain, smoke and dust, and solid waste, which lead to severe water and air contamination. Evaluating and mapping of groundwater pollution is an important aspect, because the physical, chemical and microbiological properties of groundwater determine its suitability for agricultural, industrial and domestic usages (Swarna & Nageswara 2010).

Libya faces one of the severest water shortage problems in the world. Rainfall is scarce except in the narrow coastal strip. The country has increasingly relied on its groundwater sources. In coastal areas these sources are renewed by rain each year, but the country also has vast non-renewed reserves of water underlying the desert. For a

number of years, demand for water has far exceeded supply. As a result, the country has experienced heavy over-drafting and mining of aquifers associated with the growing problems of aquifer diminution, quality worsening, and salt water intrusion (IWRM 2007).

This study, spatially analyzes the groundwater pollution in the region of Derna on the east of Al-Jabal Al-Akhdar in the northeastern part of Libya. It focuses on identifying the key factors that led to groundwater contamination, discusses its suitability for human consumption and the spatial distribution of groundwater contamination. The research strategy will be carried out as summarized in (Figure 1.1). The thesis was arranged to manifest its objectives with seven chapters followed by references list and appendixes.

Chapter one is the introduction of the study and gives a brief overview background on the study subject, problem statement, research question, aim and objective of study, research methodology, definition of terms and the thesis outline.

Chapter two discusses the literature review and gives a theoretical background of the ground water pollution problem and applied research approach. The chapter includes an introduction, theoretical background, the groundwater situation in Libya, groundwater in Al- Jabal Al- Akhdar (North-East Libya) and the evolution of the groundwater situation in Al- Jabal Al- Akhdar and Benghazi plain. This part also focuses on groundwater pollution, groundwater discharge and recharge, and groundwater for water supply. Besides, there is the application of methods in groundwater studies such as geographic information system (GIS) and water quality index (WQI).

The background and description of the study area were given in chapter three and gives a full description of the study area including the location of the study area, the climate, topography, soil and geology followed by the population growth of the study area.

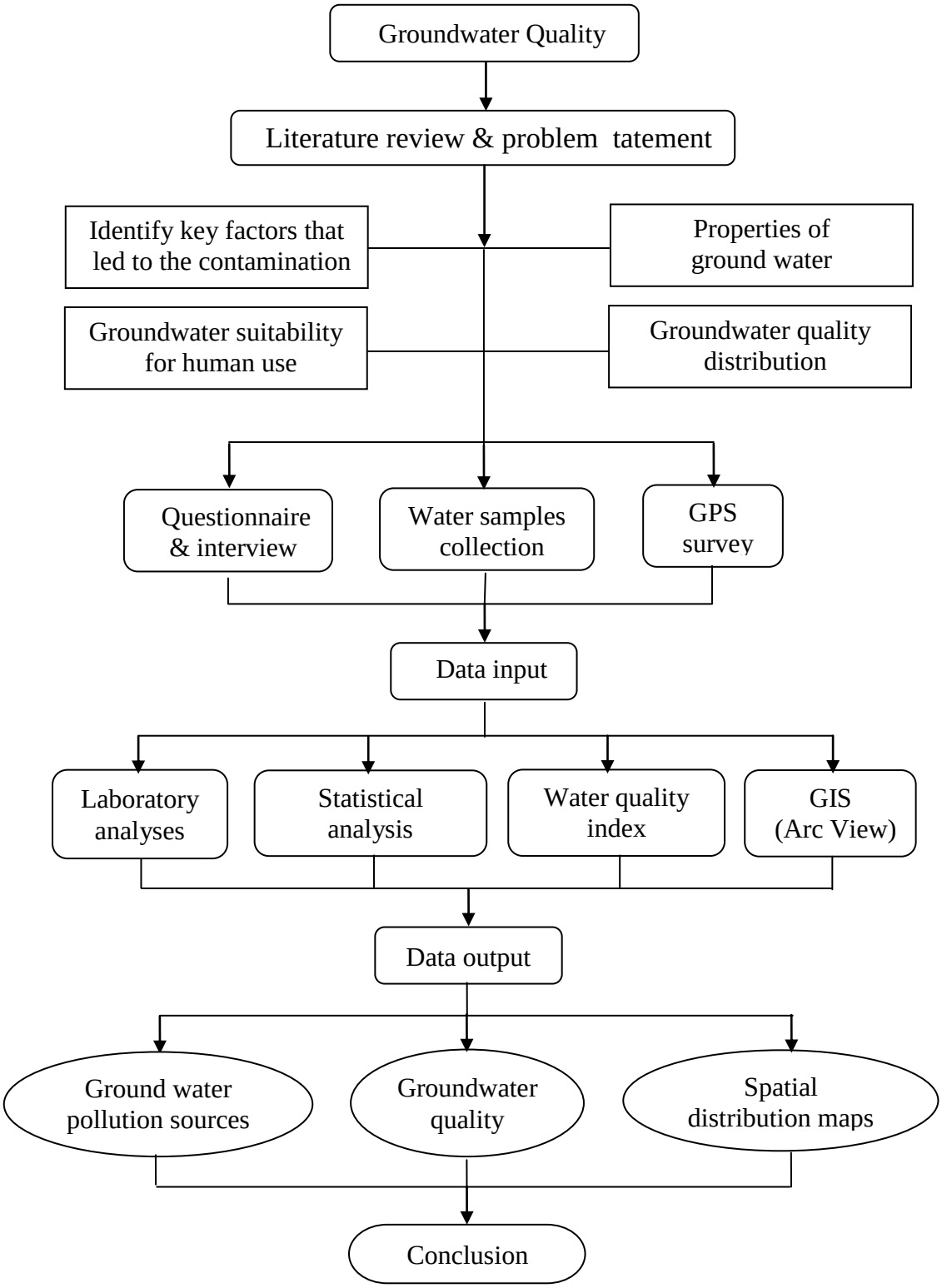


Figure 1.1 The Research Strategy

Chapter four focuses on the methodology of the study and gives a brief explanation of the methodology applied to design the architecture of the system and provide a detailed description of the prototype structure and implementation, consisting of two stages: firstly, data collection stage through questionnaires and water samples collection; secondly, data analysis stage using laboratory analysis, statistical analysis, geographic information system (GIS) analysis and water quality index (WQI).

Chapter five discusses the sources and key factors of groundwater pollution and its properties including: introduction, natural sources, anthropogenic sources and microbiological and chemical properties of groundwater. This chapter also compares the means of groundwater parameter concentrations among the region's sections.

Chapter six focuses on the spatial analysis of groundwater quality. It gives a brief background about the spatial distribution of groundwater pollution using GIS technique and shows zonation maps of the spatial distribution of water quality parameters concentrations. The second part of this chapter discusses the suitability of ground water for domestic purposes using water quality index (WQI) values.

Chapter seven focuses concludes the study and aims to draw the research conclusion and suggests future work that may be undertaken. The last chapter is chapter eight and list the cited references used in the thesis.

1.2 STATEMENT OF THE PROBLEM

The great challenge for the coming decades will be the task of increasing water supplies and protecting water from pollution to ensure water security for the steadily growing world population, particularly in countries with limited water resources. In view of the scarcity of surface water resources in the Arab Region, groundwater is the primary source of water for some of the countries and secondary source for others. It is regarded as the primary water sources in some Arab countries including Libya. Large-scale irrigation with groundwater from deep well fields and boreholes is becoming widespread in the semi arid countries like Libya (Shahin 2007).

In general, protection of groundwater from pollution is more important than the protection of surface water. This is due to the fact that the contamination of groundwater is difficult to detect, observe and control until the pollutants reach into the water, and it becomes difficult to treat, especially in the absence of monitoring stations and periodic tracking of water. In the case of treatment the cost is very expensive and takes longer time, and therefore the best and least costly treatment is to prevent pollution from the beginning.

The region of Derna, Libya lacks surface water and therefore relies on groundwater as the main source which supplies water for human use. Decrease in groundwater level as well as physical and chemical pollution is noticeable due to urbanization, economic development and population growth. As a result of population growth, urban development and sustained economy, with continuous and increasing demand of water to keep pace with this development; the groundwater quality and quantity have been changed, to the extent that several wells have been closed.

Population growth has been increasing significantly in the region, particularly in the sixties and seventies, reaching 5.9%. The population of Derna has increased from 15,891 in 1954 to 83,857 in the last Libyan census 2006 (National Authority of Information and Documentation 1954, 1964, 1973, 1984, 1995 & 2006). This rapid population growth leads to increase in different human activities (agricultural, industrial and urban) and resulting in creating wastes, which in turn affects the quality and quantity of groundwater, which is considered the main source of water in the region.

The issue of drinking water contamination is the most prominent among environmental issues in Derna region. It has been shown that 60% of the drinking water pumped directly to the consumers did not pass through the main reservoirs contrary to all health and regulatory conditions that require receiving these water the main tanks to ensure their validity and sterilized if necessary before pumping to the consumers. The analysis also proved that the water in some areas of the region is not suitable for drinking (Ashour 2008).

The main occupation of the people residing in this region is agriculture and they heavily depend on the groundwater for drinking, domestic, livestock and agricultural purposes (Adak & Purohit 2003).

With 70 tons of waste are generated daily which ends up in open places close to the residential areas, ultimately leaking with the aid of rain water to underground aquifers thus causing contamination (Elgali 2006). This is of serious concern to environmental as well as the health status of the people. Sewage is considered as the biggest source by the volume of waste and pollutants that are discharged to the land (David 1996). The sewage networks in the region were established in the sixties of last century, and they unable to accommodate the current population density, and have become dilapidated and spill out the sewage. Injection wells used for domestic sewage disposal (septic systems, cesspools, drainage wells for storm water runoff, groundwater recharge wells) are very big concern to water quality if located close to groundwater sources. Besides that the sewage treatment plant and all sewage stations lift have been out of order. Which can lead to pollutants leaking into the groundwater. Therefore, periodic monitoring of groundwater quality is necessary to safeguard its long term sustainability.

Given the importance of this region, and to safeguard human health and environmental safety from pollution risks, there was a pressing need to conduct a study on groundwater pollution in the region to examine and analyze the impact of human activities on groundwater quality, spatial distribution of groundwater quality and the suitability of such water for human use. Finally, the study will make some recommendations that could be taken to alleviate this serious environmental problem and reduce its effects.

1.3 RESEARCH QUESTIONS

This research would attempt to answer the following questions:

1. What are the natural and anthropogenic factors that led to the groundwater contamination in the region?
2. What is the spatial distribution of groundwater pollutants in the study area?

3. Is the groundwater suitable for domestic consumption in the study area?
4. What structural and non- structural measures could be taken to alleviate this serious environmental problem and reduce its effects?

1.4 AIM AND OBJECTIVES OF THE STUDY

The general aim of this study is to find whether there was groundwater pollution as a result of anthropogenic activities, and to provide information on the characteristics of groundwater quality in the region of Derna. The primary objective will be achieved through the following sub- objectives:

1. To identify key factors that led to the contamination of groundwater in the region.
2. To analyze the spatial distribution of groundwater quality in the study area.
3. To determine the suitability of groundwater for human consumption based on computed water quality index values.
4. To make recommendations to government authority and individual to reduce groundwater pollution.

1.5 SIGNIFICANCE OF THE STUDY

The importance of groundwater study lies in being a major source of drinking water and agriculture, especially in arid and semi-arid areas. The problem of groundwater contamination comes within the environmental problems that interest the geographer in the field of applied geography. Feature of this study is highlighting the nature of spatial analysis and comprehensiveness of the problem dimensions. Therefore, this study would give an insight into the problem and propose solutions, and provide assistance to planners and competent authorities to access the best ways to alleviate the widespread groundwater contamination problem and its risks. The importance of this study is to clarify and highlight the problem of groundwater pollution in the study area, to assess the quality of this vital and important resource. On the other hand, the study will contribute to determining the spatial distribution of the quality of groundwater in the region and therefore to find appropriate solutions. Furthermore, the

results of the study could also determine the locations without water pollution as the best location for populating.

1.6 THE SPATIAL LIMITS OF THE STUDY

The field work of the study began from November 2010 until February 2011for data collection, where in this period, the sample size was determined and the study data had been collected, while data analysis was extended until November 2011. On the other hand, the spatial framework of the study includes the population and sources of groundwater (wells and springs) in the area between latitudes 32˚37´ and 32˚48´ north, and between longitudes 22˚30´ and 22˚55´ east, in the northeastern part of Libya.

1.7 DEFINITION OF TERMS

During the course of this write up, some words or phrases came up that need to be defined for better clarity of the subject.

Domestic Solid Waste: It is the wastes generated by homes and all places occupied by humans, such as hotels, restaurants, shops and clubs, educational institutions, public parks and others (Zain Al-Abideen & Arafat 1992).

Agricultural Solid Waste: It includes all waste resulting from agricultural and animal activities, such as; remains of trees, crops, plants, vegetables etc. and dead animals. The amount of this waste is different depending on the type of agriculture and the method used in agricultural production (Al-Siddeq 2000).

Industrial Solid Waste: It includes all solid waste generated from various industrial activities, and these wastes differ significantly in quality and degree of risk, depending on the type of industry, manufacturing methods and materials used (Sharaf 2000).

Waste water (Effluent): It is the water generated from houses, institutions and factories. This water is turbid, has a dark color and contains a large amount of

bacteria, fungi, viruses, insects etc. These organisms may cause dangerous diseases like typhus and cholera (Ghraibh & Al-Frhan 2000).

Waste of water waste Treatment (Sludge): It is organic and inorganic materials mixed with water, produced from water waste treatment (Ghraibh & Al-Frhan 2000).

Chemical Measurements of water: Chemical examinations show quality and concentrations of several organic and non-organic pollutants that are presen in the water either naturally or as pollutants (Ghraibh & Al-Frhan 2000).

TDS: It is a crude measure of the total concentration of inorganic solids in water. It is measured by evaporation (Gray 1994).

PH: It is a measure of the degree of acidity or alkalinity of water. Water with a pH of 7 is considered neutral. If the pH is below 7, it is classified as acidic, while water with a pH greater than 7 is said to be alkaline (Al-Taira 2004).

Electrical Conductivity (EC): It is the ability of electrical current to pass through water, which in turn is related to the concentration of ionized materials present in it. Most dissolved inorganic materials present in the water are in ionized form and contribute to electrical conductivity (Swarna & Nageswara 2010).

Total Hardness: It is a measure of the ability of water to the concentration of calcium and magnesium in water and is usually expressed as the equivalent of CaCO3 concentration (Swarna & Nageswara 2010).

Fertilizer: It is any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more plant nutrients essential to the growth of plants. A recent assessment found that about 40 to 60% of crop yields are attributable to commercial fertilizer use (Wikipedia).

Pesticides: It is any chemical material used to control animal and plant pests. These include fungicides, herbicides and insecticides (Gray 1994).

Water Quality Index (WQI): It is a form of average derived by relating some variables to a common level and combining them into a single number. It summarizes information by combining several sub-indices of the most significant parameters into a single-variable expression (Srikanth et al. 2011).

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the details of the previous studies that relate to this research. This discussion will provide theoretical background on the spatial and temporal analysis of groundwater contamination in the field of Geographic Information System (GIS) in terms of support, investigation and analysis of groundwater contamination data in the study area. This chapter has been divided into seven sections, in order to provide a better understanding on groundwater studies. The first section provides introduction about the theoretical background; the second section discusses general background about groundwater; the third part highlights the exchange of water between surface and groundwater (groundwater recharge and discharge), the fourth section describes the situation of groundwater in Libya, the next section explains groundwater contamination in the urban, agricultural and industrial area, the sixth section elucidates the role of groundwater in water supplies, and the last section highlights the application of geographic information systems in groundwater studies.

2.2 THEORETICAL BACKGROUND

This part gives general information related to the subject of the study. The information includes the meaning of ground water, its advantages and its uses, the specifications and standards that must be available in the sources of water, to be potable, and the quality of groundwater compared with surface water as well. This information helps to easily identify the suitability of water for drinking in the area of research.

The ground water is defined as the water stored in the ground, generally water gets accumulated underground due to rain. The ground water will either be renewed consequent or periodic rain, or it will not be renewed instead will be confined in the geological rock formations as a result of nominated rain water during the ancient times (Suleiman 1993). Ground water is an extremely important source of water in arid and semi- arid areas, and it is also considered the supplementary source in humid areas, where the distribution pattern of rainfall does not match the pattern of water demand, where its quality will be better than surface water (Mamdouh 2007).

The ground water has a lot of advantages such as, high quality, hardly affected by seasons, storage without spatial limitations and more available quantities as against surface water. However, it constitutes only 30% of all freshwater on the earth (Table 2.1). The demand of fresh ground water is increasing consistently, due to the augmentation of global population and incessant economic growth, and the loss of surface water value due to pollution. Despite these advantages, ground water has some disadvantage such as, high mineral content, and the possibility of land subsidence, high cost of extraction and the risk of saltwater intrusion (Gualbert 2001).

Table 2.1 Distribution of Water and Fresh Water on the Earth

Form	**Volume,10^6km3**	**%**
Distribution of water		
Oceans and seas	1351.0	97.5
Fresh water	35.0	2.5
Total quantity of water	1386.0	100.0
Distribution of fresh water		
Ice	24.4	69.7
Surface water	0.1	0.3
Groundwater	10.5	30.0
Total quantity of fresh water	35.0	100.0

Source: Gualbert 2001

In most cases, groundwater is cleaner than surface water, as it is usually protected against the risk of pollution by the soils and rock layers. Hence, groundwater is used as drinking water, in most of the countries. However, rising world population,

changes in usages of land and rapid industrialization have heavily affected the quality of groundwater, due to the leakage of pollutants underground, which has put the groundwater at risk (Wilhelm et al. 2005). The quality of groundwater includes its physical, chemical, and biological properties. Temperature, turbidity, color, taste, and odor make up the list of physical water quality parameters. Since most groundwater is colorless, odorless, and without specific taste, people are typically most concerned with its chemical and biological qualities (Thomas 2003).

In some areas, groundwater may contain natural substances that exceed the safe levels, which can eventually restrict or even prevent its direct use; such as seawater intrusion and soluble natural substances like arsenic, fluorine, nitrate or sulphate, which might cause serious health concerns (Wilhelm et al. 2005). Whereas, anthropogenic activities are considered as the primary root cause of groundwater pollution, especially in densely populated areas and where human use of the land is extensive. The most important anthropogenic factors in the contamination of groundwater are: waste disposal practices, injection wells, storage and handling of materials and wastes, leakages from underground storage tanks, mining practices, industrial activities and agricultural activities (Figure 2.1) (David 1996). However, any other activity that involves in the discharge of chemicals or other garbage into the environment, followed by their accumulation in the groundwater, will certainly contaminate the groundwater and seriously affect its usability; furthermore it is difficult and expensive to purify the contaminated groundwater. Groundwater is often used as a source of drinking water and therefore consumption of water containing intestinal pathogens may spread disease (Mahfouz et al. 2008).

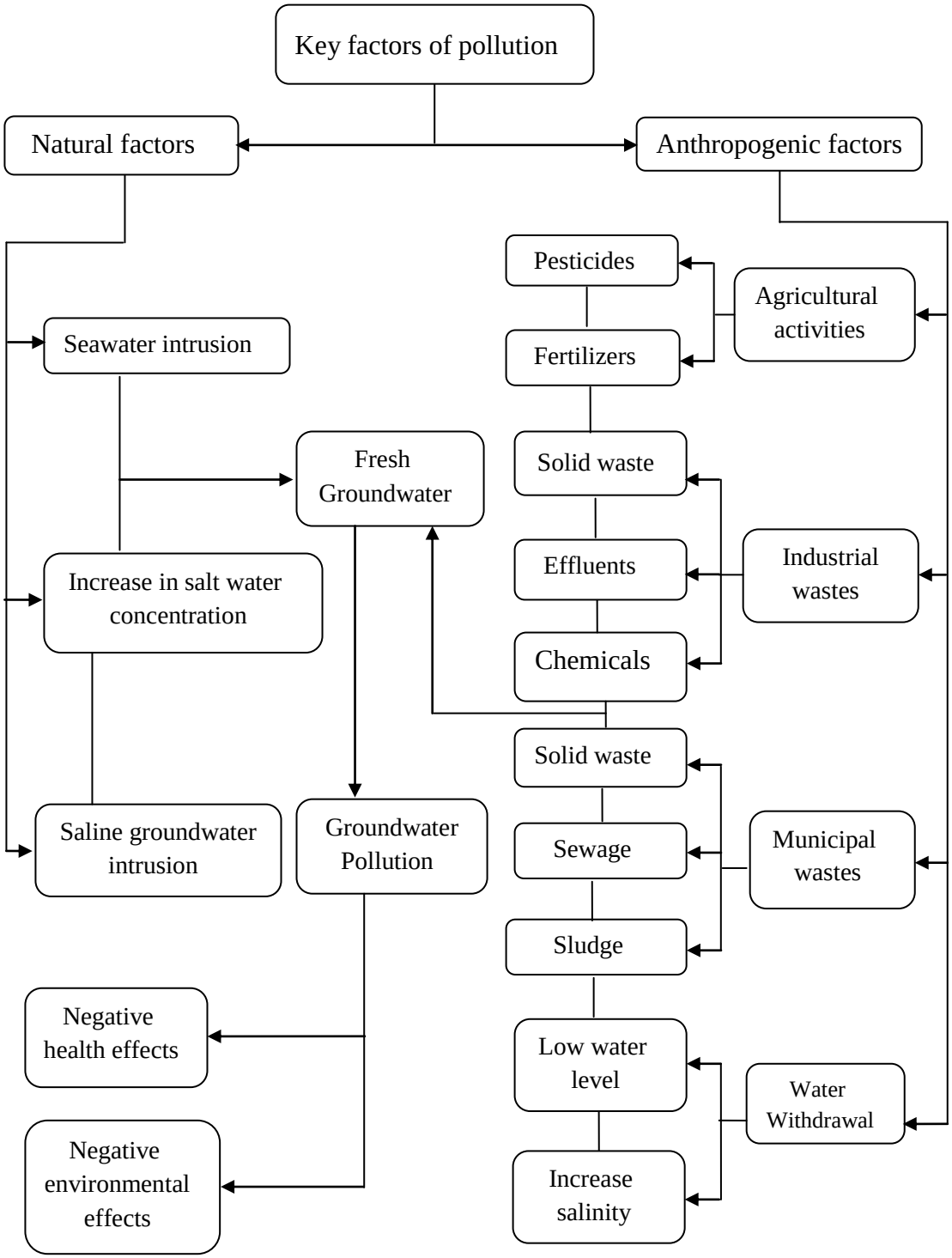


Figure 2.1 The Stages of Groundwater Pollution

According to Brooks (no date) most of the Middle East and North Africa countries (MENA) have reached or are rapidly approaching the limits of their indigenous water supplies. The technology is available and the economics are favorable, but there are deficiencies of better management of the limited fresh water resources. In MENA, fresh water is used for irrigation, and agriculture is so embedded in regional societies, and thus the most difficult part of the shift depends on a gradual return to predominantly rain fed farming ways. The water problems in the region result from a combination of natural and anthropogenic forces, such as, drought and population growth. Quantity of water has been a source of stress and concern in MENA. The low water per capita, is the most serious concern in MENA. MENA countries can be divided into three groups according to availability of water:

- Iran, Iraq, Lebanon, Sudan, Syria, and Turkey are fairly well- endowed with water.
- Algeria, Egypt, Israel, and Morocco form a middle group.
- Libya, Jordan, Tunisia, and countries of the Arabian Peninsula are poorly endowed.

In general, usage of water in the MENA region can be divided into five categories: household, municipal, industrial, agricultural, and ecological (Table 2.2).

Table 2.2 Water Use in the (MENA) Region

Sector of Use	**Percentage**
Households	3 – 20
Municipal	3 – 10
Industrial	1 – 10
Agriculture	60 -90 (includes recycled water)
Ecological	Variable

Source: Brooks no date

Any substance that upon reaching the aquifer, changes the quality of water and makes it unclean or otherwise unsuitable for particular purposes are called pollutants of groundwater. Sometimes the substance is a manufactured chemical, but just as often it might be microbial contamination. Contamination also can happen from naturally occurring mineral and metallic deposits from rocks and soil (William 2010).

Drinking water must be completely free of pesticides, phenol compounds and aromatic compounds. (Table 2.3) illustrates the permitted level of heavy metals and cyanide in water. (Table 2.4) shows the allowable proportion of chemical materials arising from pollution, the proportions of chemical substances that are found naturally in the water must not exceed the limits, as shown in the (Table 2.5), in order to protect its safety as drinking water.

Table 2.3 Proportion of Heavy Metals and Cyanide the Water

Material	**Maximum limit mg/L**
Arsenic	0.05
Cadmium	0.005
Cyanide	0.05
Mercury	0.001
Selenium	0.01
Lead	0.05
Chromium	0.05
Barium	1.00
Silver	0.05

Source: National Center for Standards Specification 1993

The percentage of chlorine in the water must be between 0.2 and 0.5 parts in million. Biologically and microbiologically, drinking water should be free from micro fauna and worms that may cause diseases, as well as from bacteria, algae and fungi respectively.

According to the National Center for Standards Specification, Libya (1993), drinking water must be safe for human consumption. It must be completely free of turbidity and must not contain any color resulting from pollution, it also should be free of materials that are harmful to health, and contains remnants at the allowable amount of chemicals, used in the process of water purification. Moreover, the PH value must not be less than 6.5 and not more than 8.5.

Table 2.4 Allowed Proportion of Chemical Materials Arising from Pollution

Material	**Maximum limit. mg/L**
Detergents	0.2
Total of halogenated compounds	0.25
Nitrate	1.0
Ammonia	0.5
Fats	1.0
Mineral oils	0.01
Carbon chloroform	0.5
Phosphate	-
Chemical oxygen demand	10
Biological oxygen demand	6
Hydrogen sulfide	0.1
Total of sulfide	0.2

Source: National Center for Standards Specification 1993

Table 2.5 Proportion of Chemical Substances Found Naturally in Water

Material	**Optimum limit (mg/L)**	**Maximum limit (mg/L)**
Total Dissolved Solids	500	1000
Copper	0.01	1.0
Iron	0.1	0.3
Magnesium	30	150
Aluminum	-	0.2
Sodium	20	200
Potassium	10	40
Fluoride	1.0	1.5
Manganese	0.05	0.1
Sulfate	200	400
Zinc	5.0	15.0
Calcium	75	200
Chloride	200	250
Hardness. As $CaCO_3$	200	500

Source: National Center for Standards Specification 1993.

2.3 GROUNDWATER DISCHARGE AND RECHARGE

This section discusses the process of exchanging water between surface and ground levels (groundwater discharge and recharge). The exchange generally provides major pathways for the transfer of dissolved matter. Even in areas, where there is no anthropogenic groundwater contamination, an alteration in the groundwater or surface water exchange rate could have significant effects on the quality and quantity of water (Schmidt et al. 2010).

Groundwater recharge is the natural or artificial means of water infiltration down through the soil, to reach the water table. Consequently the excessive withdrawal of water from groundwater aquifers, leads to the declination of its level. Groundwater recharge is more important, especially in regions with large demands for groundwater supplies, where such resources are the key to the economic development. Thus, rainfall is considered as the main natural source for replenishment of moisture in the soil water system and recharge of groundwater. In addition, the sources of recharge include: rivers, streams, irrigation water etc (Amitha 2000).

James et al. (2004) defined the groundwater recharge as "precipitation that infiltrates into the soil and is not evapotranspired. Instead, the infiltrated precipitation moves downward to a depth below the root zone of the surface vegetation, where it cannot be removed by that vegetation through the uptake and evaporation. In such a depth, it is considered available to enter the soil's saturated zone and become groundwater".

The sources of a groundwater recharge system include both, natural and anthropogenic. Natural sources of groundwater recharge include, precipitation, lakes, ponds, rivers, and from other aquifers. On the other hand, anthropogenic sources of recharge include irrigation losses, excessive irrigation, leaking water mains, sewage and septic tanks. Groundwater recharge has been divided into two parts such as: direct recharge from the percolation of precipitation and indirect recharge from runoff. The key environmental factors that control recharge of groundwater are: climate, soils and geology, vegetation and land use, topography, and depth to water table,

(Sophocleous 2004). (Figure 2.2) shows the role of groundwater recharge in the general hydrological cycle.

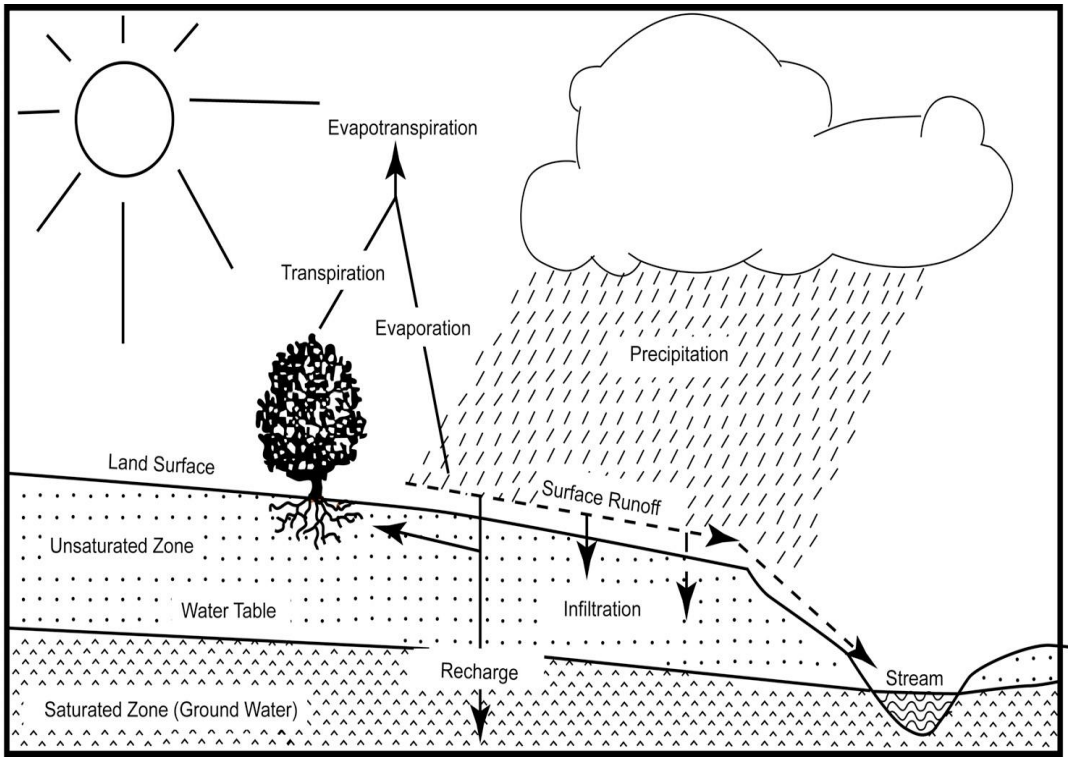


Figure 2.2 Groundwater Recharge in the Hydrologic Cycle

Source: James et al. 2004

"Groundwater discharge is the volumetric flow rate of groundwater through an aquifer" (Wikipedia 2010). Groundwater discharges in unconfined aquifers, where the vertical height for the aquifers is greater than its corresponding sediment surface elevation (David et al. 2005).

Groundwater discharge is estimated as the residue between the different inputs and outputs from the precipitation, surface runoff, evaporation, etc, by using water balances. Due to the presence of strong density gradients between seawater and freshwater and the confounding effect of tides, the discharge of groundwater in coastal environments is considered more complex than in the inland environments. On the other hand, the presence of density gradients along the coastal area tends to focus groundwater discharge along the shoreline. For instance, at Cockburn Sound in Western Australia, most of the groundwater discharge from an unconfined sand aquifer

occurs within 10 meters of the shoreline, and the fresh groundwater discharge from unconfined aquifers would be expected to reduce salinity in the coastal areas (Sebastien et al. 2005).

Groundwater leaks from the surface slowly downwards through aquifers and finally discharges into lakes, rivers, and seas or oceans. The process of groundwater discharge directly into sea waters is called as submarine groundwater discharge (SGD), and it is an invisible phenomenon. The groundwater existing in the confined aquifers is under heavy pressure. However, the water will rise above the top of the aquifer if a well penetrates the aquifer, and due to this pressure within the aquifer the water moves upwards. The groundwater discharge has been observed in the marine environment over the centuries (Reide et al. 2009).

2.4 WATER REGIONS DISTRIBUTION IN LIBYA

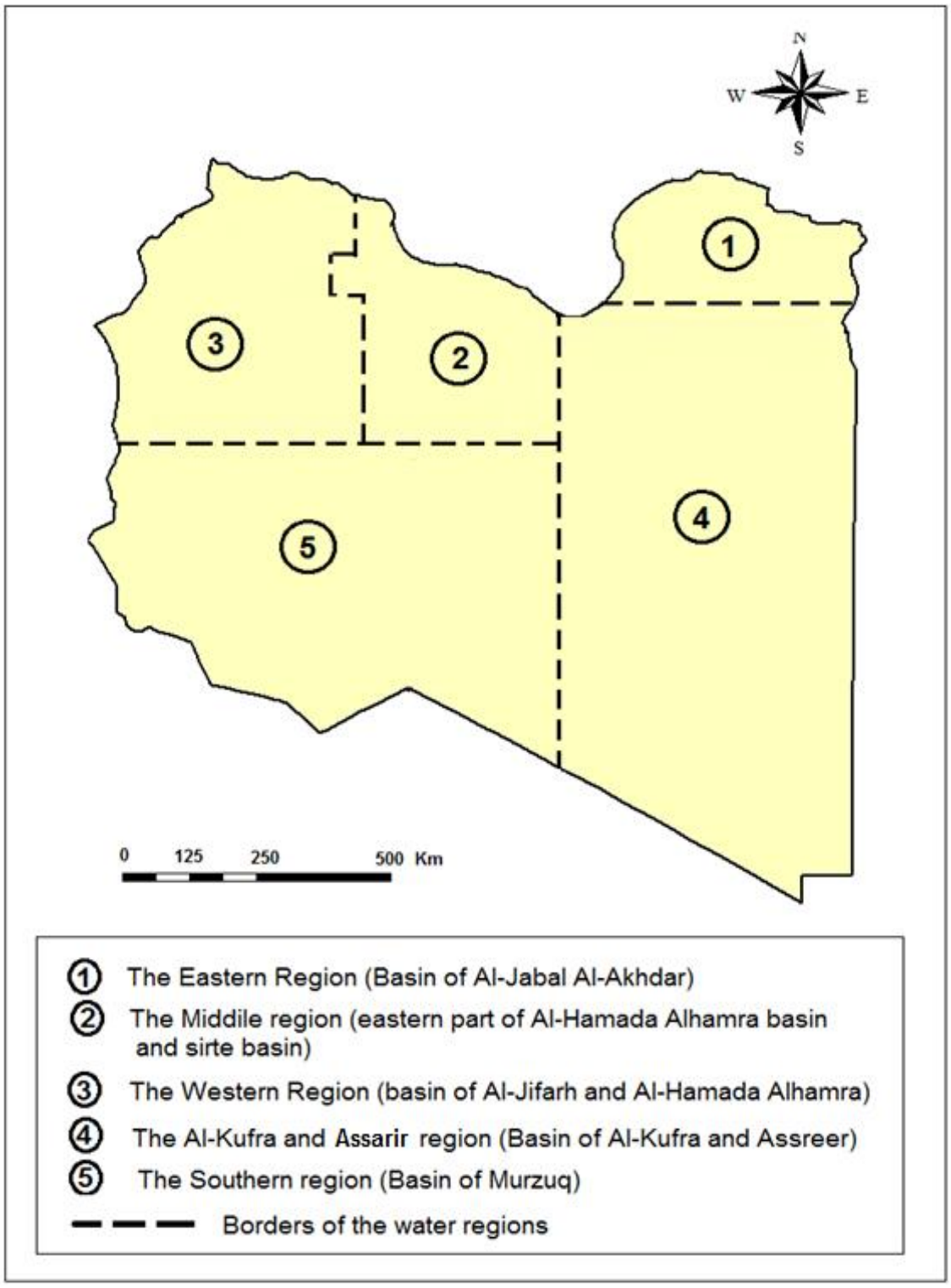
As it is shown in (Figure 2.3), there are five principal regions with substantial water resources in Libya:

1. The Eastern Region (Basin of Al-Jabal Al-Akhdar)

The eastern region includes Al Jabal Al Akhdar as well as Benghazi Plain and extends to the eastern border with Egypt. The main reservoir groundwater in this region exists in the tertiary limestone formation, sitting above an impervious layer of late Cretaceous formation. This region is characterized by the existence of cracks, through which water moves northwards towards the Mediterranean Sea, at an estimated annual rate of 250 million m^3. Another part of the water in this reservoir moves southward towards south Al-Jabal Al-Akhdar region at an annual rate of approximately 150 million m^3 per year. The estimated annual recharge is approximately 340 million m^3 (Bashir 2005).

On the other hand, the depths of these reservoirs reach about 600 meters. The production is estimated by more than 76,521,374 m^3 per year with varying quality from good to bad or unfit for drinking, while the annual consumption (urban, agricultural and industrial) is estimated to be 38,6707,034 m^3 .The excessive withdrawal and the limited

recharge, in addition to seawater intrusion have led to sharp decline in the water level and deterioration of quality (G.W.A 2006).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1 The Eastern Region (Basin of Al-Jabal Al-Akhdar)
2 The Middile region (eastern part of Al-Hamada Alhamra basin and sirte basin)
3 The Western Region (basin of Al-Jifarh and Al-Hamada Alhamra)
4 The Al-Kufra and Assarir region (Basin of Al-Kufra and Assreer)
5 The Southern region (Basin of Murzuq)
Borders of the water regions

Figure 2.3 Map of the Water Regions Distribution in Libya

Source: G.W.A 2006

2. The middle region (eastern part of the Al-Hamada Alhamra basin and the Sirte Basin)

This region is located in the central part of Libya and is considered as a transition area between Jifarah Plain in the west, Al-Jabal Al-Akhdar in the east and Fezzan in the south. It extends from longitudes 14° 00' to 19° 00' east and from the Mediterranean to latitude 28° 00' north. The depth of this water region varies between 30 and 800 meters. The region is characterized by Tertiary and Quaternary formations containing shallow aquifers, particularly along the coast, while the deep reservoirs are located on the late Cretaceous formations (Bashir 2005). The production of this area is approximately 38,98,200 m^3 per year, while the consumption is 280,000,283 m^3 per year. The high withdrawal of water in different regions has made the water level to plunge down heavily during the past 30 years (G.W.A 2006).

3. The Western Region (Basin of Al-Jifarh and Al-Hamada Alhamra)

The region of Al-Jifarh and Al-Hamada Alhamra is situated in the northwestern part of Libya along the Tunisian border. The aquifers in this region have been existed since the early Cretaceous and Triassic formation and contain varying degrees of discharge and depth (Bashir 2005). The groundwater in this region is present in a group of underground reservoirs, some of which is replenishable, and some non-replenishable such as those found in deep reservoirs which existed since ancient time. The water level ranges from 10 to 80 meters below the ground surface in the surface aquifer, whilst in the deep aquifer the water level ranges between 40 to 120 meters below the ground surface. The water quality varies from good to saline water. The estimated production of wells in the shallow aquifers ranges from 20 to 50 m^3 per hour. The discharge from the deep artesian wells ranges from 30 to more than 100 m^3 per hour. Studies carried out by the General Water Authority showed that withdrawal quantities of groundwater may exceed annual normal recharge of the groundwater reservoirs, which is estimated to be 270 million m^3 per year. This quantity is increasing annually due to the overexploitation of water, which has led to a decline of water level and the deterioration of its quality (G.W.A 2006).

4. The Al-Kufra and Assarir region (Basin of Al-Kufra and Assarir)

This region covers most of the eastern and southeastern part of Libya and extends towards Egypt, Sudan and Chad. It is characterized by aquifers in the Nubian and Tertiary sandstone formation. This formation is very thick and deep, it reaches to about 3000 meters depth, especially in the middle of the Al Kufrah Basin. The water quality in this region is generally good and it is not replenishable, especially in the deep layers (Bashir 2005). Al-Kufra and Assarir region considered as the largest aquifer in Libya in terms of water quantity and quality. The region is divided into two aquifer basins: Al-Kufra and Assarir Basins. The Al-Kufra and Tazrbu Basins includes about 4369 wells, with pumping rate ranging between 50 to 360 m^3 per hour for each well, however, the annual consumption is estimated to be 427,500,000 m^3 per year. On the other hand, the Assarir Basin includes about 728 wells with pumping rate reaches to 274 m^3 per hour for each well. The annual withdrawal in Assarir Basin is approximately 507,000,000 m^3. As a result of lack of fresh water in northern regions, a large quantity of this water has been transferred to coastal regions in northern Libya. Monitoring wells in the region have recorded a limited decline in water level and deterioration in its quality; consequently the excessive withdrawal of water and fertilizer usage as well as the excessive consumption of water have led to crack on the earth's surface (G.W.A 2006).

5. The Southern region (Basin of Murzuq)

Murzuq Basin is considered as the second largest water basin in Libya. It is located in the southwestern part in the country. Groundwater in this region is present in two main aquifers; the Nubian sandstone aquifer in the early Cretaceous and Triassic formation and second aquifer is present in Devonian and Cambro-Ordovician formations. Due to the lack of rainfall, the groundwater in this region is non-replenishable (Bashir 2005). This region contains a large number of wells divided into five areas with varied depths. The estimated annual consumption of water in this basin for all purposes is 1454 million m^3 per year. There is a significant decline in the water level, due to the huge withdrawal, as a large part of this water has been transferred to Al-Jifarh plain in the north- western part of Libya (G.W.A 2006).

2.5. GROUNDWATER SITUATION IN LIBYA

This section highlights the past and current situations of groundwater in Libya, and particularly in the northeastern region, where the study was conducted. It discusses the groundwater quality and quantity, the extraction, productivity of some wells and springs, as well as the amount of change in the water level, where, the groundwater is considered as the main source of fresh water in Libya.

Libya is an arid country and most of its parts are desert, in which fresh water is perpetually scarce. Rainfall is rare- only five percent of the country receives more than 100 mm of rain each year. Libya has relied on groundwater reserves for a long time to quench its thirst; but surging demand has stressed supply, and many coastal groundwater aquifers have become brackish with an influx of seawater. In the mid-fifties, oil exploration in the vast southern desert of Libya has revealed a possible solution and a valuable source for water supply in the form of "fossil water". Where, 40000 years old of pure water has been stored in the old groundwater aquifers, below the desert sands (National academy of science 2008). As mentioned earlier, groundwater is considered as the main source of fresh water in Libya, providing a vital supplement to surface water sources, and constitutes about 95% of water resources (Suleiman 1992). However, the availability and quality of groundwater are vulnerable both to climatic change and over-abstraction, and in regions where the water table has lowered (Elaswed no date).

It is difficult to obtain high quality water in Libya. Most of the wells that produce good quality in the south of the country far away from populated areas in the northern parts of the country. However, planners are more concerned with the fact that exploitation from the stockpile is non-renewable and will not be fed by rainwater (El-Talhi 2003).

Libya occupies the north central part of the African continent, and shares major groundwater basins with neighboring countries. The climate of Libya is considered as a dry desert climate, especially in the central and southern regions, and

characterized by the wide variations in temperature between summer and winter seasons as well as scarcity and irregularity of rainfall.

The highest population density is concentrated in the northern regions of the Libya, where soils are suitable for agriculture. There are two major water sources in Libya; surface and groundwater sources, but the former contributes less than 3% of the total water supply of the various human activities. In order to use and control these sources, around 16 dams and several reservoirs have been constructed to collect more than 60 Mm^3 per year. In the Al-Jabal Al-Akhdar, Jabal Nefusa and the central zone the natural springs of low to medium discharge provide water for different uses. On the other hand, there is deterioration in water quality, due to seawater intrusion and saline water from neighboring aquifers, as well as leakage of pollutants, resulting from different human activities. The development of all the available resources has become mandatory, to meet the growing demand for water. For the water resources development planning, a strong legislation to regulate the use of shared water resources must be applied and necessary actions must be taken for the conservation of water (Salem no date) as follows:

- Exchange of information focused on future development plans.
- Defining the allowed quantities to be used by each country based on regional study results.
- Monitoring extraction and resulting draw-down.
- Setting rules for waste disposal control and prevention of industrial, chemical, and petrochemical pollutants.

2.5.1 Groundwater in Al- Jabal Al- Akhdar (North-East Libya)

Al Jabal Al Akhdar area stores groundwater less than any other areas because of the existing classes of karst, and due to the huge rate of drainage through springs between 24 and 48 million cubic meters per year. The quality of water in the Al Jabal Al Akhdar is between acceptable and good levels. Previous studies have shown that there are four confined reservoirs located above the level of water (Figure 2.4).

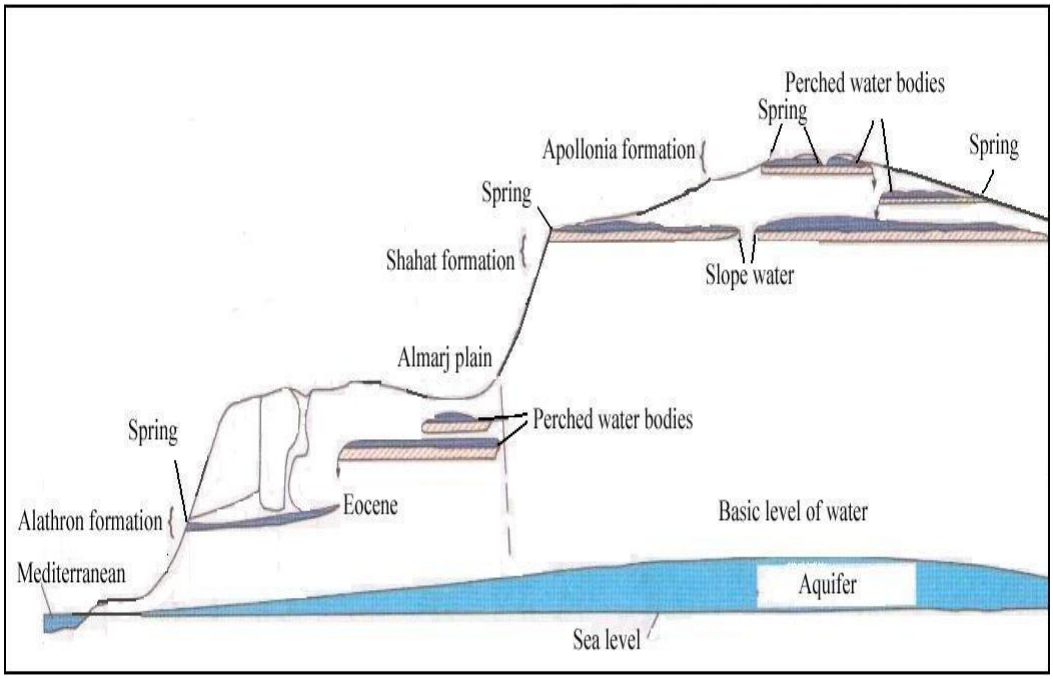

Figure 2.4 The Main Basic Aquifer in Al-Jabal Al-Akhdar

Source: El-Talhi 2003.

The water table is located at depths ranging between 200 and 500 meters from ground surface, The limited groundwater can be found at depths of several meters to hundreds of meters below the surface of the earth, The water moves through underground channels, and gaps from a water division line in the northern direction towards the sea, and in the southern direction towards the basin of Al-Jaghbub. The springs abound in the northern part of this area, where this current study is carried out (El-Talhi 2003).

2.5.2 Evolution of groundwater situation in Al- Jabal Al- Akhdar and Benghazi plain

The water pumped from the Benghazi plain in the early sixties of the last century (for different purposes) had been estimated at 6 million m^3 (El-Talhi 2003). The quality of the shallow water was poor in the south and good in the north of the region, but the above water has tended to salinity. Marshes and ponds had represented the manifestations of the water level near the earth's surface near the coast.

(Table 2.6) shows data on springs and wells in the coastal areas in the late fifties and early sixties. The field of Benina was the main source to provide water to Benghazi, and it has registered a decrease of approximately 0.7 meters between 1949 and 1961.

Table 2.6 Data on the Wells of Benghazi Plain in Late Fifties and Early Sixties of the Last Century

Wells location	**Depth (m)**	**Water surface (m)**	**Productivity (m^3 /hour)**
Benghazi (Garden city)	20	16.46	-
Benghazi (Garden city)	40	31.72	-
Benghazi (Garden city)	146	64.38	-
Benina	142	83	45
Buatnai	27.9	25.12	-
Alkwyfia	148	31.06	14
Alkwyfia	13.7	3.98	30
Sidi Khalifa	30	5.8	1.6
Sidi Khalifa	40	12.35	34.7
Bersis	48.7	14.47	13

Source: El-Talhi 2003

It was clear that the groundwater in this region faces the risk of pollution from two sources; seawater intrusion and saline water that exists under a layer of fresh water. As recommended in the sixties of the last century, the pumping from all the wells in the region must not exceed five cubic meters per hour. In Al- Jabal Al- Akhdar most of groundwater supply relied on spring water up to the sixties of the last century, besides a very less number of pumping wells had good quality of water. (Table 2.7) gives data about springs and wells in Al- Jabal Al- Akhdar area in the period of the late fifties and early sixties. In all the Al- Jabal Al- Akhdar area, the total volume of groundwater extracted for various purposes was approximately about 10 million cubic meters per year in the period of the late fifties and early sixties. In the late seventies the total volume of groundwater consumption had reached to 172 million cubic meters per year. Increase of the extraction had affected negatively either the water level or the water quality in the period (1960 - 1977). Water level had recorded a decline ranging

between 0.5 – 2 meters in Benghazi plain, and one meter in Al-Marj plain through the period from 1970 to 1977 (El-Talhi 2003).

Table 2.7 Data on the Wells of Al- Jabal Al- Akhdar in Late Fifties and Early Sixties

Wells location	Depth (m)	Water table (m)	Productivity (m^3 /hour)
Al-Abyar	33.4	31.81	-
Al-Abyar	309	265	1.2
Sidi Mhous	57.6	54.85	-
Jrdas Al-Abeed	7	-	0.75
Al-Zerdah	140	50-125	3.8
Al-Zerdah	183	117.3	11.4
Taknes	11.3	9.42	1
Taknes	12.7	11.40	6
Farzoga	158	112.94	1
AL-Marj plain	52	42.52	-
AL-Marj Plateau	76	47	5
Om Al- Resm	9.5	8.64	0.1
Batta	164	98.96	1
Massa spring	-	-	4.6
Al-Qubba spring	-	-	4
Shahat spring	-	-	13
Al- Dbboseia	-	-	510
Stoa spring	-	-	45
Al-Athron spring	-	-	330

Source: El-Talhi 2003

In general, groundwater extraction and consumption continued to increase over the last two decades of the last century in the whole region, (Table 2.8) shows that there was a significant increase of water extraction due to population growth and human activities. Consequently, this was enough to bring about a serious deterioration in water quality. Accordingly, the total volume of groundwater extraction in Al- Jabal Al-Akhdar water area had reached to 342 million cubic meters per year in 2000. However, the extraction has started to decrease due to the arrival of water form Man-made River Project (El-Talhi 2003).

Table 2.8 The Development of Water Extraction in Al- Jabal Al- Akhdar Area and Benghazi Plain

The region	The extraction in mid-seventies (Million m3/year)	The extraction in 2000s (Million m3/year)
Benghazi	85.0	180.0
Al-Bayda	3.0	50.0
Derna	4.0	77.0
Al-Marj	10.4	35.0

Source: El-Talhi 2003

It is noteworthy that springs are the most important water sources in this study area, of which El-Belad and Abu-Mansour are major springs . Both of them are located in the basin of the Derna valley in the southern region, these springs are the main sources that provide the water to the region for all domestic uses. The need of water has increased due to the continued population growth, urban development and other human activities, therefore it has become crucial to search for water sources, and therefore ten deep wells were drilled in Bab-Shiha (south-west of the study area) in the period (1961-1976) and the production of water ranged between 175 - 2700 m^3 / day. Later, three more wells were drilled in the same area, which produced between 240-300 m^3 of water per day. Consequently due to the increased demand of water series wells were drilled until their number reached to 47 wells in the 1990s. But more than 16 of those wells have been closed due to breakdown of pumps or water contamination, which made them not suitable for human use (Elgali 2006).

2.6 GROUNDWATER POLLUTION

This section discusses groundwater quality and the different key factors that affect the quality of water. Furthermore, it also explains how the researchers have collected and analyzed the samples of water, the main elements that they relied for the analysis processes and the outcomes of those studies.

(Galip et al. 2005) has studied the soil and water contamination by industrial, agricultural, and municipal wastes in order to investigate the impact of these pollution sources on both, surface and groundwater in the Eskisehir plain, Turkey. According to

the Turkish Standards for water sampling and analyzing methods, the water and soil samples were collected from different locations in the region of study. The study has revealed that high concentrations of some heavy metals were found in both surface water and groundwater, and high amounts of phosphorus and nitrogen and sulfur compounds were found as well. Accordingly, the groundwater in the mentioned region is not suitable for drinking.

Daly and Daly (1984) has stated that the groundwater in Ireland comprises of approximately 25% of the total water used and the wells, especially in areas that are the bedrock of limestone are contaminated. The results of the study have also revealed that due to the leaking water waste and farm waste, 50% of wells in Ireland contain bacteria and large quantities of ammonia, and other main pollution sources.

Sacchidananda & Prakash (2006), have stated that the disposal of treated and untreated industrial effluents has become a regular practice for some industries, and attempted to take the environmental and socio-economic impacts of industrial effluent irrigation in different industrial locations at Mettupalayam Taluk in India. They have identified that the disposal of industrial sewage constantly on land has increased groundwater contamination, and the quality of groundwater of shallow open wells surrounding the industrial areas has deteriorated, furthermore the irrigation with contaminated groundwater has increased the proportion of salt in the soil.

The practice of throwing solid waste in open dumps has become common practice in most countries of the world. It has many environmental effects such as soil and water pollution. There are many groundwater sources near the site of the landfill in Nagpur, India. Hence, (Paras & Vijaya 2005) had attempted to determine the impact of various factors on the quality of groundwater, and analyze the groundwater quality. Statistical analysis has been used to represent the relationships between many nested variables. They have collected samples from sources around the landfill sites at lower elevation, for physical and chemical analysis, bacteriological and heavy metal parameters.

According to (Mukul & Ravinder 2008) groundwater is considered as the major source of water needs for domestic purposes in the urban and rural areas in India, and it is pure and safer than surface water as it is concealed within the earth. They have collected samples of groundwater and analyzed physically and chemically from 41 different locations in Panipat city, to assess the suitability of groundwater for domestic purposes. The analysis included color, taste, odour, pH, electrical conductivity (EC), total hardness (TH), total alkalinity (TA), sodium, potassium, calcium, magnesium, carbonate, bicarbonate, chloride, sulphate and fluoride. They have identified that there was a high concentration of dissolved salts. Their study has shown a positive and significant, correlation of (EC) with total dissolved salts (r = 0.979), total hardness (r = 0.507), sulphate (r = 0.453), total alkalinity (r = 0.725). Total hardness is positively and significantly correlated with magnesium (r = 0.833) and sulphate (r = 0.687). While the total of alkalinity was found to be positively and significantly correlated with bicarbonate (r = 0.992). Fluoride was higher than permissible limits in most of the samples.

Passarella et al. (2002) had attempted to find a possible approach to evaluate the risk of groundwater quality deterioration. The work team had used Disjunctive Kriging (DK) in their study to the conditional probability estimation of an exceedance of certain threshold in a specific region. The methodology of their study relied on the following steps:

- Monitoring the quality of groundwater.
- Estimation of the general statistics of the distribution of the concentration data.
- Analysis of the structural to assess of the spatial behavior of the sampled pollutant.
- Use of the DK to transfer the obtained data.
- Kriging estimation and mapping the concentration values in the region to provide the accessibility results.
- Evaluation of the probability conditions.
- Applied of a non-parametric statistical test to evaluate temporal information.

- Identify the classification of the risk of groundwater quality.

The samples of nitrate concentration values were collected from approximately 90 sampled wells in the spring and autumn from 1990 to 1996. During this period, no distinct difference was found in the nitrate concentration in the two seasons. The investigation in the region can be plotted in the form of maps of spatial risk. The agriculture effects on groundwater results in a high nitrate pollution that limits its use for drinking purposes.

Pradeep et al. (2006) have studied the groundwater pollution around Tarapur industrial area that located the Arabian Sea Coast in India. Consequently they have suggested remedial measures that may be used to solve the same problem in other industrial areas on the Indian Sea Coast. The researchers had collected around 131 samples randomly from different sources to identify the chemical properties of water, such as (pH), electrical conductivity (EC), total dissolved solids (TDS), hardness, calcium, etc. EC and pH were measured immediately in the field using portable digital EC and pH meters, respectively, while all other parameters were determined in the laboratory. In the process of sample collection, they have attempted to take at least one sample from every village around the study area. In general, the results of their study revealed that the study area has hard water and has high salinity, and this may be due to the intrusion of seawater. Even though the groundwater might not be suitable for drinking, it is suitable for irrigation purposes. The PH readings were low, and increase of heavy metal concentration in the water, which may be due to the random disposal of industrial effluents in drainage canals that link the creek, and finally this caused the contamination of groundwater in the region.

Ikem et al. (2002) have studied the evaluation of groundwater quality characteristics in two of the largest cities in Nigeria (Ibadan and Lagos). The two areas relied on wells as the main sources of drinking water. About 51 groundwater samples had been monitored seasonally for two years to assess the quality of groundwater and compared them with drinking water standards of the World Health Organization (WHO). Their study results revealed that the analysis of fresh refuse composition of the two waste sites in (Table 2.9).

Table 2.9 Analysis of Fresh Refuse Composition of the Ibadan and Lagos Waste

#	Vegetable matter	Paper	Metals	Plastics	Glass	Textiles
Ibadan	78%	10%	5%	3%	2%	2%
Lagos	59%	17%	8%	12%	2%	2%

Source: Ikem et al. 2002

The groundwater quality comparison has revealed that some samples were polluted, and all samples had total coliforms greater than zero, and other samples were polluted by ammonia due to leakage of sewage tank to drinking water wells, which creates health concern for humans.

The effects of anthropogenic activities and natural processes on groundwater quality are the major serious problems for sustainable development in the region of Wadi Fatimah, Saudi Arabia. (Sharaf & Subyani 2011) have taken 80 groundwater samples and analyzed them for 17 water quality parameters such as: As, Zn, P, Pb, Ba, B, Si, Al, Li, Cu, Fe, Hg, Mn, Cd, V, and Rb. The aims of the study were to evaluate the levels of groundwater contamination of toxic elements and their spatial distribution, and to identify the possible anthropogenic and natural sources of contamination in the region. The data were analyzed using cluster analysis (R and Q method) and factor analysis. The variables were clustered into three major groups and showed a high correlation between major ions (As, Pb, Cu, Cd, Hg), which indicated that the surface water is recharged during the dissolution of the plutonic acidic and intermediate igneous rocks of the study area. Factor analysis indicated that the first three factors account for 85% of the total variance. The first factor revealed high loading of Al, Li, B and Cd, which suggested an interaction between water and geological formation. The second factor represented high loading of As, Pb and Hg, which suggested human and agricultural activities. The third factor represented high loading of Si and Fe, which may have resulted from water/weather rock interactions.

Al-Sabahi et al. (2009) studied compositions of landfill leachate and groundwater pollution in Ibb city, Yemen. The study was aimed to assess the groundwater contamination due to landfill leachate. They collected leachate samples at

three different locations at the landfill, and the groundwater samples were collected from five wells to identify the potential effects of leachate percolation into the groundwater. The main finding in their study indicated that there are four boreholes out of five have been polluted, and the physical and chemical parameters concentrations were more than the acceptable standard levels for drinking water.

In the city of Benghazi northeast Libya, the groundwater pollution has been studied by (Al-Taira 2004). The study was aimed to determine the groundwater sources that were exposed to pollution and to identify the degree of groundwater deterioration and impact of population, urbanization and economic growth on the groundwater sources. The results of the study showed that the groundwater contains different concentrations of harmful elements, and some of them exceeded the allowed limits. The maximum concentration of nitrate was 48mg/L in Al-Hawari area, TDS was 4720 ppm in Teca, TH was 4750 mg/L in Ain Al-Zayna, Ca was 362.8 mg/L in Al- Kwyfia, Ma was 912 mg/L in Ain Al-Zayna and coliform bacteria was 1820 germ/100 mL in Ain Al-Zayna. The study also revealed the disposal of solid and liquid wastes have led to water contamination.

2.7 GROUNDWATER FOR WATER SUPPLY

This section presents the contribution of groundwater for water supplies. Groundwater is considered the most important resource around the world, and it is often available and can be developed relatively cheaply near where it is required. As well as, it is usually enough and suitable for drinking water supply with little or no treatment. Only with reliable pure water supplies, the households can build sustainable livelihoods; and thus eliminating poverty (MacDonald & Calow 2009). The following are some of the factors that constitute towards a secured supply:

- The water should be enough in quantity to meet all demands.
- The water is safe to drink and is not polluted, and available in times of drought, when increase the demand.

- The water is accessible to all in a community and within a reasonable distance of all households.
- The supply prices are affordable to all and can be easily maintained.

Any project or program for rural water supply must include the points presented below to achieve a secure groundwater supply:

- Wells should be sited effectively.
- Maintenance; communities must participate in all stages.
- Water supplies should be engineered appropriately.
- The quality of the water must be known.
- Supplies and groundwater resources must be protected from contamination.

Increases in water demands have led to the need to establish the water supply and demand management to economically and efficiently operate a system within budget while meeting user demands. An extensive range of concerns resulting from modifying supplies and demands must be considered in devising and developing a plan for water supply.

Groundwater is assumed to require only disinfection, and thus it can be delivered directly to all users (Chung et al. 2008). In the United States for instance, more than 90% of the public water supply comes from groundwater sources. In Thailand groundwater has been used for drinking purposes for the past five decades. Groundwater uses can be included municipal, industrial, and agricultural supplies. In Thailand 50% of the groundwater is used as drinking water, 10% for municipal supply, 20% for industrial supply, 15% of agricultural practices, and 5% for other activities (Anat 2002).

It is possible to develop groundwater near the population centers at relatively low cost and supply it to rural areas. Furthermore, it is more reliable than surface water, and the underground aquifers can often store a much larger amount of water than their

annual recharge, hence the reliable supplies can be maintained even during periods of low rainfall. In addition, groundwater is mostly good quality, and it has more protection than surface water from surface contamination as well. Because of this, approximately 80% of the African rural population relied on groundwater supplies for domestic and other water needs. On the other hand, the contribution of groundwater supply for agricultural purposes is very little; it is estimated at only about two million hectares in Africa. In Asia the groundwater irrigation has key advantages in terms of reliability (Roger & Alan 2009).

The daily water demand in Mombasa, Kenya is 200,000 m^3, and the available quantity is 130,000 m^3 obtained from water sources from outside the region. The shortage of 70,000 m^3 is supplemented by groundwater sources in the region. In other words about 35% of water supply rely on groundwater. In addition, as the reticulated supply experience frequent breakdowns, groundwater sources very often become the major source of water available in the district. In fact, 13,286 out of the 183,540 households in the region, are almost permanently dependent on groundwater (Daniel no date).

In the Mediterranean region, groundwater resources are either the main sources of freshwater in drier areas or are needed to supplement surface water sources in humid areas. Groundwater constitutes more than 50% of the available water resources in the Mediterranean islands and it is practically the only water resource in the Sahara desert extending from Egypt to Morocco in northern part of Africa. Groundwater exploitation in the region has increased dramatically during the last decade, mainly due to an increase in irrigated agriculture, tourism and industry (Elaswed et al. No date)

Libya relies heavily on groundwater for water supply, where it represents more than the 97% of water needs in the country, of which 85% for agriculture, 11.5 for domestic and 3.5 for industrial purposes. (Table 2.10) shows water supply and demand in Libya. For several years, huge water deficit amounting to about 1.270 billion cubic meters per year occurred and this deficit is made up from non-renewable groundwater resources (Abufayed & E1-Ghuel 2001).

Table 2.10 Water Supply and Demand Situation in Libya in 1998

Water supply		Water demand	
Source of water	**Amount 10^6 M^3 year**	**Area of demand**	**Amount 10^6 M^3year**
Ground	2553	Agricultural	3335.3
Surface	61	Domestic	452.6
Desalination and Wastewater reuse	42	Industrial	135.9
Total	2656	Total	3923.8

Source: Abufayed & E1-Ghuel 2001

2.8 METHODS APPLICATION IN GROUNDWATER STUDIES

Different techniques and methodologies have been developed to evaluate the environmental effects associated with groundwater pollution including the concept of aquifer vulnerability. The studies of Geographic Information Systems (GIS) applications have contributed towards understanding, how the analyses are carried out and how the this tool should be employed. This part reviews some of the studies related groundwater that used the technique of GIS for spatial and temporal analysis.

Geographic Information System (GIS) is a useful and strong technique for displaying spatially related information for many disparate uses. It is defined as ‘‘a collection of information technology, data and procedures for collecting, storing, manipulating, analyzing, and presenting maps and descriptive information about features that can be represented on maps (James 2004). In addition, it suitable for investigating environmental problems, furthermore most of the environmental problems have a clear spatial dimension and the spatially distributed models can interact with GIS. This technical method has allowed successful integration of water quality variables into an understandable format. (Bilgehan & Ali 2008).

The Mersin aquifer is located in the southern part of Turkey and it is considered as the main source that provides the water for domestic, industrial and agricultural use in the region. The intensity of industrial land use has a negative impact on groundwater quality, and this is a major concern. Accordingly, (Demirel 2006) by employing photometric methods had determined heavy metal in groundwater and

identified the main factors influencing the pollution of groundwater in the area. He used the following elements: geological data, water samples, photometric determination and evaluation of data with GIS. The field study included quality of water measurements, heavy metals measurements and chemical analysis. On the other hand, the GIS software was used for generating and digitizing thematic maps. Many thematic maps were produced by using GIS and by overlaying these maps; the all polluted areas were determined. In many locations, some of the heavy metals exceed their acceptable limits due to the disposal of industrial waste.

Anat (2002) has stated that the wide usage of pesticides has increased the possibility of groundwater pollution in Thailand. In the agricultural areas the pesticides mixed with rain water into groundwater, and result in deteriorating the groundwater. His study used GIS to assess the potential groundwater pollution, and the main objectives of the study were: to produce maps to identify the relative weakness of groundwater in the study area, to make comparison between the produced maps and the real data of groundwater quality, and to develop a model for predicting the degree of susceptibility of groundwater to contamination by pesticides. The study focused on five variables, soil texture, slope rate, land use, well depth, and rainfall, due to they are most likely to affect leakage of pesticides to groundwater. Concentrations of pesticides were found in 90 wells in the region, and the produced maps illustrated that there was a relative vulnerability of groundwater to be contaminated by pesticides in the study area. The vulnerability maps produced contain of a number of grid cells in which each cell is assigned a value showing the relative vulnerability of groundwater to pesticide pollution. The researcher had developed a surface model-by overlaying the five variables as mentioned above - for predicting the susceptibility degree of groundwater to pollution by pesticides “vulnerability model”. This is expressed as shown in (Equation 2.1).

$$V = \Sigma^{5} (W_n * Cn) \quad \text{.....(2.1)}$$

$n = 1$

Where:

V = Vulnerability score of a cell or mapping unit.

W = Weight or influence factor for data layer n.

C = Value or class assigned to a cell or mapping unit in data layer.

North Carolina has a good quality of groundwater, and it considered as the main source of drinking water for about 55% of the population; while in rural regions this proportion increases to 97%. The spread of pollution has led to an awareness of its vulnerability to contamination. Petroleum derivatives, leaked from storage tanks can migrate through the soil to aquifers. Most of the individual wells have not been tested and the water from those wells was being used consistently by the residents who do not have full knowledge about its quality or suitability for human use. The above - mentioned study was aimed to confirm the role of GIS and spatial analysis as a tool for investigating groundwater contamination, as well as to review the need to test water quality in private wells. The researcher relied on freely available data and information from the Guilford County Environmental Health Department. The findings revealed that GIS is useful for groundwater pollution studies; it also confirmed the need to test the quality of water in private wells. The identified major pollutants to groundwater were gasoline, heating oil and diesel fuel. Several maps were produced and showed the distribution of groundwater wells, pollution incidents and development and wellhead buffers and contaminated groundwater (Kathleen 2008).

GIS technique was used to map, query, and analyze the data of nitrate concentration in groundwater as one of the important water quality parameters in Konya city in Turkey. Around 189 wells locations have been determined by using a Global Positioning System GPS receiver (Bilgehan & Ali 2006). The outcomes of their study have revealed that a minimum nitrate concentration of 0.4 mg/L was observed in 140 wells, and the maximum concentration was 32mg/L and in the city center. On the other hand, the nitrate concentration in the water has increased rapidly due to a variety of factors such as wells location in the center of the city, groundwater level fluctuation and other anthropogenic activities. In some wells the concentrations exceed the allowed limits of water standards in Turkey, and other wells have been closed. Geographic Information Systems was used as a monitoring system in order to assess the quality of water more efficiently. The study had also applied Spearman’s rho test to nitrate

concentrations and well depth, a correlation coefficient of r = 0.259 and r = 0.261 P value is > 0.001 were obtained from the data of 1998 and 2001, respectively. In this investigation Spearman test revealed that there was only limited positive relationship between nitrate concentrations and well depth.

Mevlut & Tayfun (2010) aimed to evaluate the spatial changes of groundwater nitrate concentrations by using geo-statistical methods based on data from 119 groundwater wells. They applied geo-statistical methods as a convenient tool to make decision on controlling the behavior of hydrochemical parameters in groundwater. Geographic Information Systems was used for the application of the universal Kriging method with cross-validation to estimate concentrations of nitrate in groundwater. The statistical distribution of the untransformed data for groundwater nitrate concentrations was positively skewed. The spatial distribution map of groundwater nitrate concentration has shown that the highest groundwater nitrate concentrations occurred in the center of the city. While, the lower values of groundwater nitrate concentrations were found at the margin of the city, and the values in the study area were below the permissible limit. On the other hand, the study found that, there was no potential threat to human lives.

Spatial distribution of groundwater quality in the corporation area of Rajahmundry (South India) and its surrounding areas has been studied by using Geographic Information System (GIS) technique (Venkateswara et al. 2009). The GIS was used to store, analyze and display the distribution of spatial data, for investigating the information related to groundwater quality. Fifty water samples were collected and analyzed for PH, EC, TDS, TH, Ca, Mg, Na, K, CO3, HCO3, CL-, NO3, SO4 and fluoride using standard techniques in laboratory. The spatial distribution maps of groundwater quality have been prepared using the GIS spatial interpolation technique for all the parameters in the study area. GIS zonation maps showed that the spatial distribution of PH values ranged from 6.4 to 8.2, and the higher range of PH is observed in central wells in central, eastern and western parts of the area. The TDS values varied between 160 and 2972 mg/L, and the highest values were concentrated in the central, western and eastern parts of the study area. The TH, Ca and Mg values varied from 80 to 1462 mg/L, from 10 to 224 mg/L and from 4 to 273 mg/L respectively. Chloride is

the second dominant ion in the groundwater, and varied from 10to 1048 mg/L. The highest values of Cl were observed from the samples collected from Kalvacherla a small village in Andhra Pradesh, South India. The concentration of sulphate ranged from 120-225 mg/L which was less than the groundwater on the east coast of Andhra Pradesh. The values varied from 0.1 to 1.5 ppm.

In order to achieve the aim of testing the performance of spatial interpolation techniques for mapping groundwater quality (Taghizadeh 2008) has applied IDW, kriging and cokriging methods in their research. Seventy three groundwater samples were taken from wells in Ardakan-Yazd plain in Iran, for predicting spatial distribution of some groundwater parameters namely TDS, TH, EC, SAR, Cl-and SO4. The results of the study have revealed that geo-statistics methods had a more considerable accuracy than IDW method, and cokriging method increased the prediction accuracy and had less RMSE for all the studied parameters. On the other hand, the majority of the studied parameters had high skewness, due to its incomplete number of samples and unsuitable distribution. The results have also indicated that, the effective range of most of the qualitative parameters of groundwater are close to each other indicating their high correlation. The deterioration of groundwater is concentrated on east and North-West of the region.

Geographic Information system (GIS) can be a helpful tool for developing solution for water resources problems, to evaluate the quality of water, identifying availability water and understanding the natural environment on a local and / or regional scale. (Swarna & Nageswara 2010) carried out the physical and chemical analyses for different parameters of groundwater in Badhrawathi Taluk, Karnataka, South India, for domestic use as well as developing of Water Quality Index (WQI), and mapping of spatial distribution using GIS techniques. Inverse distance weighted (IDW) raster interpolation technique of spatial analyst module in Arc GIS software was applied to produce the spatial distribution maps of selected water quality parameters namely alkalinity, total dissolved solids (TDS), total hardness (TH), chlorides (Cl), fluorides (F) and water quality index (WQI). The researchers calculated WQI according to the following (Equation 2.2):

WQI = Antilog [$\sum_{i=1}^{n}$ wi $\log_{10}$ q_i] .....(2.2)

Where:

wi = weightage factor of i^{th} parameter.

qi = quality rating of i th parameter.

wi = calculated as shown in (Equation 2.3).

$wi = k/s_n$ ..... (2.3)

Where:

k = constant $= \frac{1}{\frac{1}{Vs1}+\frac{1}{Vs2}+\cdots+\frac{1}{Vsn}}$

sn = standard value of i^{th} parameter.

qi is calculated as shown in (Equation 2.4).

$qi = 1\frac{Va-Vi}{Vs-Vi}) \times 100$ ..... (2.4)

Where:

Va = actual value obtained from laboratory analysis of i th parameter

Vs = standard value of i^{th} parameter.

Vi = ideal value.

(pH=7 and 0 for all parameters).

The results obtained from the physicochemical analysis have revealed that the pH ranged between 7.0 and 8.31 and the alkalinity varies from 172 to 372 mg/L during the pre-monsoon and ranges from 170 to 368 mg/L during post-monsoon season. EC varied from 686 to 3552 μS/cm for pre-monsoon water samples, while it ranged between 680 and 3600 μS/cm in post-monsoon samples. The TH of the pre-monsoon

season ranged between 266 and 1152 mg/L, while it ranged from 256 to 1134 mg/L in post-monsoon season. The magnesium hardness of the pre-monsoon waters ranged between 3.3 and 85.2 mg/L while it was 3.3 to 84.7 mg/L in post-monsoon waters. The mean values of sodium varied from 34.3 to 174.2 mg/L in the pre-monsoon season, while during the post-monsoon season it ranged between 30.3 and 170.2 mg/L. The values of potassium varied from 8.1 to 32.4 mg/L during pre-monsoon season, whereas, in post-monsoon water samples it ranged between 7.9 and 30.4 mg/L. Nevertheless, the concentrations were within the permissible limits. The chloride values concentrations were less than 250 mg/l in 66% water samples. The sulphate concentrations ranged from 44.6 to 150.2 mg/l and from 40.6 to148.6 mg/l during pre-monsoon and post-monsoon season respectively. The value of fluoride has ranged between 0.6 and 1.2 mg/l and from 0.5 to 1.0 mg/l in pre-monsoon and post-monsoon respectively. WQI ranged from 37.85 to 107.32 in pre-monsoon, and from 39.27 to 82.86in the post-monsoon season. The spatial distribution of water parameters and WQI are concentrated in the southwestern parts of the study area.

Hamad (2008), used GIS for spatial analysis of the groundwater levels and hydrochemistry in the southern part of Al Jabal Al Akhdar, Libya, to analyze the pattern and spatial distribution of groundwater levels and hydro-chemical data using statistics and GIS to determine depth levels, flow directions, and delineating groundwater divides. In this area, differences in water quality have been identified, where the water quality in the northern part has a high value and more suitable for drinking than the water in the southern part. While for agriculture both of them are suitable, according to the composition of chemical components.

2.9 WATER QUALITY INDEX

Nair et al. (2006) studied the groundwater quality and assessed its suitability for drinking at six places in the north-eastern part of Libya viz. El-Marj, Albayda, Shahat, Susa, Ras al-Hilal and Derna from November 2003 to March 2004, by determining the physicochemical parameters and water quality index. The water quality index of all six places was calculated based on (Equation 2.5).

$$Wi^{n} = \frac{K}{1Vi} \quad \text{.....(2.5)}$$

Where:

Wi = Unit weight of the chemical factor.

Vi = Standard (desirable) limits.

K = Constant of proportionality.

The value of 'K' was calculated as (Equation 2.6).

$$K = \frac{1}{\sum_{i=1}^{15} \frac{1}{Vi}} \quad \text{.....(2.6)}$$

Regarding to the rating scale, each factor had been assigned a rating value (Vr) to calculate WQI(Equation 2.7).

$$WQI = Vr \times Wi \quad \text{.....(2.7)}$$

The temperatures of water samples averaged 15.1 ˚C, pH values were alkaline and dissolved oxygen values were in safe ranges. Electrical conductivity (EC), Total Dissolved Solids (TDS) and hardness of water at all places mentioned above, except Susa were within the standard limits. Alkalinity of well water at all six places exceeded, chlorine and chloride level except at Susa, where the level was within the acceptable limits. The above- mentioned studies did not observe any fluoride and nitrate contaminations in the wells, and only very low values of phosphorus, manganese, chromium, iron and zinc were recorded. Copper in the water of the wells was generally high, and at Susa and Ras al-Hilal, it exceeded the acceptable limit. The WQI of the six studied samples have revealed that well water of Albayda and Shahat were good for drinking and were only slightly polluted, whereas those of El-Marj, Ras al-Hilal and Derna were moderately polluted. However, the well water of Susa was excessively

polluted and was unsuitable for drinking. Appropriate suggestions were made to develop the quality of groundwater in north-eastern part of Libya.

Ashwani & Anish (2009) used Water Quality Index (WQI) to investigate the water quality of River Ravi at Madhopur, Gurdaspur District, India. Eight water parameters were analyzed to determine the WQI namely; pH, total dissolved solids (TDS), total hardness (TH), calcium(Ca), magnesium (Mg), total alkalinity, dissolved oxygen (DO) and electrical conductivity (EC). The WQI was calculated according to the weightage and rating scale of the parameters based on (Equation 2.8; Equation 2.9; Equation 2.10).

$$\mathrm{Wi} \propto \frac{1}{\mathrm{Vi}} \text{ or } \mathrm{Wi} = \frac{\mathrm{K}}{\mathrm{Vi}} \quad \text{..... (2.8)}$$

Where:

K = Constant of proportionality.

Wi = Unit weight of the factor.

Vi = Maximum desirable limits.

The value of ‘K’ was calculated as the following:

$$\mathrm{K} = \frac{1}{\sum_{\mathrm{i}=1}^{8} \frac{1}{\mathrm{Vi}}} \quad \text{..... (2.9)}$$

The rating ranged from 0 to 100 and was divided into five intervals. The rating Vr = 0 implies that the water is severely polluted, while the rating Vr = 100 implies that the water is clean. The numerical value is then multiplied by a weighting factor that is relative to the significance of the test to water quality. The sum of the resulting values is added together to reach an overall water quality index as the following:

WQI = Wi x Vr ..... (10)

The WQI values for the river ranged from 54.8 to 97.88. The values of WQI showed that the water was free of any impurities at the sampling site except for 2-3 months, where its values were less than 70.

2.10 CONCLUSION

This chapter attempted to give an idea and background on several previous researches related to this study. It has reviewed the general theoretical background, groundwater recharge and discharge, situation of groundwater in Libya (particularly in the northeastern region), an analysis of groundwater contamination, groundwater in water supplies, and some methods applied in groundwater studies and the application of geographic information systems as a tool for groundwater analysis. The next chapter will discuss the research methodology, which will highlight the sample size and technique and data collection and analysis.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

3.1 INTRODUCTION

This chapter discusses the study area based on its general characteristics such as location, climate, geology, soil and water resource of the area. This general description of the study area is necessary to build a background on the nature of the study area, and also to support the results of spatial analysis by providing some justifications for the interpretations.

3.2 HISTORICAL OVERVIEW OF THE REGION OF DERNA

In the mid sixth century BC, the term Derna had not been mentioned as the name of the city or site by historians about the region of Cyrenaica (northeastern part of Libya). The existing caves and other monuments in Derna indicate that this area was populated even if in limited and confined spaces. Some historians had believed that Derna was populated before the invasion of the Greeks and it was known as "IRASA", and it had been taken by Libyans as the Marmarica territory; which extends from the east of Derna to the Egyptian's border (Al-Trabelsi 1999).

Although the name Darns (Derna) has been included in the writings of the Greeks geographers like Ptolemy and has appeared on nautical maps, the importance of this city only appeared in the Byzantine period in which there was a special religious center in that era. This region was slightly dilapidated at the beginning of the Arab conquest, but it quickly regained its activity in the late fifteenth century, when a

group of Arabs migrated from Spain stabilized the region, hence it prospered rapidly especially in the late of the seventeenth century (Sharaf 1996).

3.3 LOCATION OF THE STUDY AREA

The study area stretches between latitudes 32˚37′ and 32˚48′ North and between longitudes 22˚30′ and 22˚55′ East. It is located on north-eastern slopes of Al Jabal Al Akhdar area, in north-eastern part of Libya. The region is bordered by the Mediterranean Sea in the north, and extends from the Annaqah valley in the west to Al-Khaleej valley in the east, includes Derna City and Al-Ftaih agricultural region. It is 90 km west and 175km east of Al-Bayda and Tobruk respectively as shown in (Figure 3.1). This region is one of the most populated urban centers in the eastern region of Libya. Brisk economic activities in the area are due to the presence of seaport (Habib 1973). Derna city is the main urban center in this region and as it is a wonderful ancient city, it is attracted by a lot of tourists. The old city is home to Ottoman architecture that consist of several historical and religious places, in addition to some scenic beaches and the Derna waterfall, which are located in the south of the region.

3.4 THE CLIMATE OF THE STUDY AREA

The study area has a Mediterranean climate, which is one of the best climates on the surface of the earth in the belt of subtropical alternate atmospheric circulation. In general, the climate is hot and dry in the summer, warm and rainy in the winter. The climate in the summer is determined by zone of a stable high pressure situated over the Mediterranean Sea. Whereas, in the fall , winter, spring seasons, the climate conditions are determined by the cyclonic activity of the ascending air masses in the temperate latitude zone. The climatic conditions in the study area are unstable and depend on the distance from the sea and the altitude of the region (El-Asswad 1995).

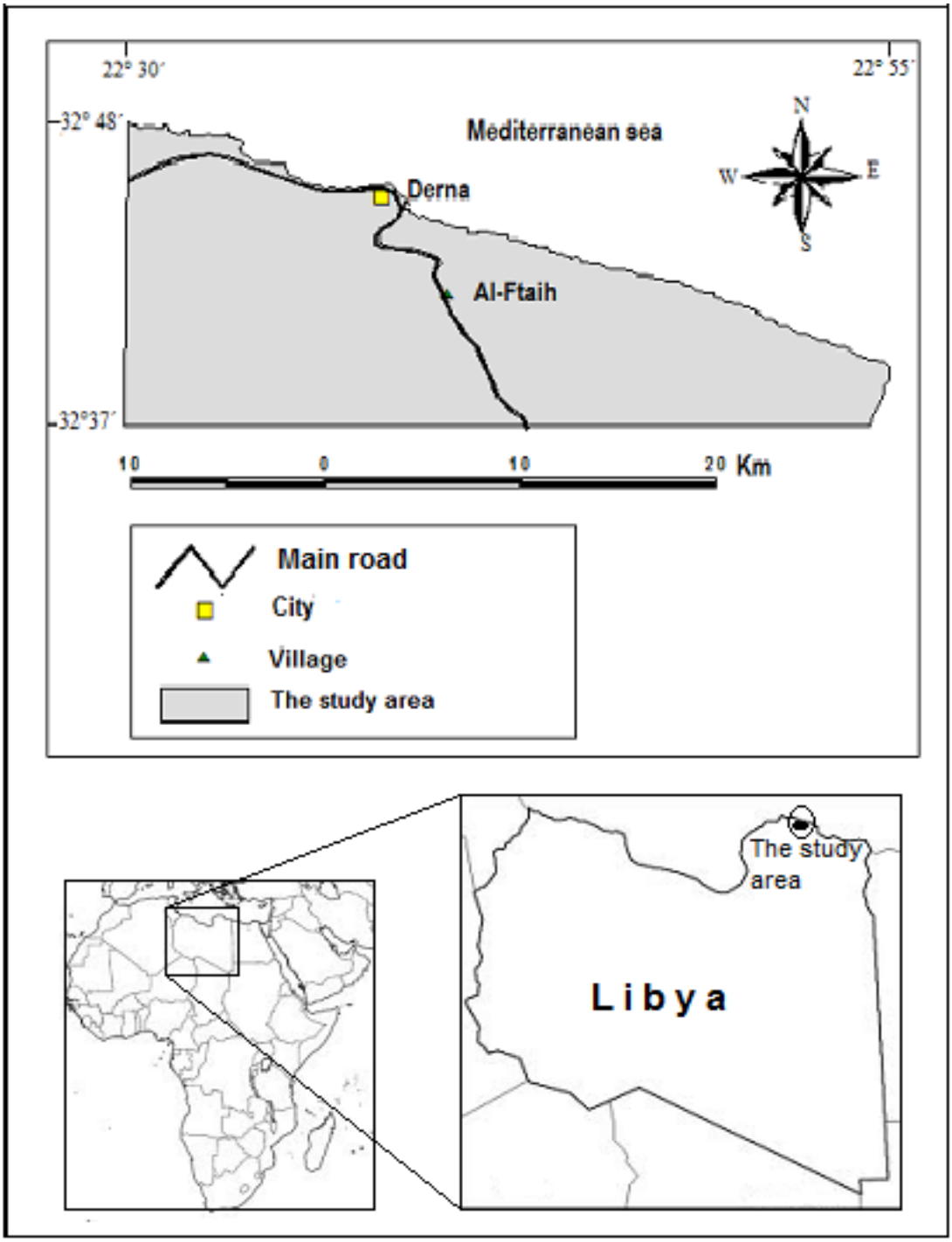

Figure 3.1 Location of the Study Area

3.4.1 Temperature

Temperature is one of the most important elements of climate, because it affects other elements of the climate. In the study area, generally the mean air temperature in summer is two or three times higher than the winter. The temperature averages tend

to be moderate, with annual mean of 20.2˚C in Derna city and 18.8˚C in Al-Ftaih town.

Lowest monthly temperature is recorded in January with an average of 14.2˚C in Derna and 12.3˚C in Al-Ftaih, but the daily minimum is around 11˚C Derna and 7 ˚C in Al-Ftaih in the same month. The temperature begins to rise gradually until it reaches maximum height, which is 26.1˚C in Derna and 25.3˚C in Al-Ftaih during the month of August. The highest daily temperature in August is 28.9˚C in Derna and Al-Ftaih (Figure 3.2). The temperature begins to decline slightly due to the impact of the sea. This decrease in the temperature continues until the winter, which is characterized by warmth in the coastal regions. It is also in this period the sun begins its annual journey in the south towards the equator, which makes up its rays oblique, and thus serve to lower the temperature in such areas.

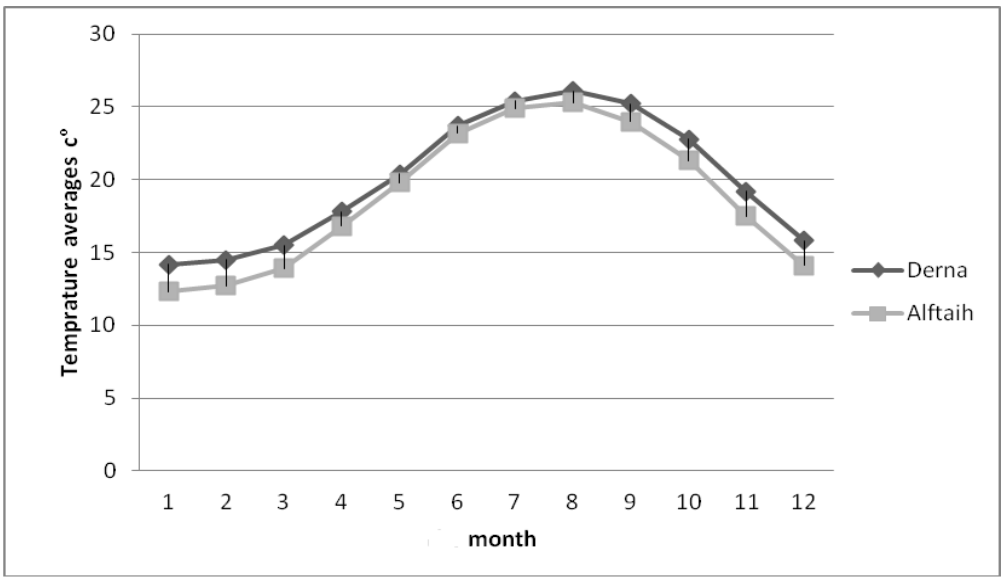

Figure 3.2 Monthly Averages of Temperature in Derna Weather Stations (1960-2000) and Al-Ftaih Weather Stations From (1975 – 2000)

Source: Department of meteorology

3.4.2 Rainfall

Rainfall is another important weather element. It is the main source of groundwater. Rainfall in the study area, begins in the winter (October to April) as the other areas in

particularly in Green Mountain and generally in Libya, while the summer is quite dry. Occurrence of rain depends on the passage of air depressions that invades the Mediterranean from the west, or as a result of the convergence of cold air masses from the north with tropical air masses from the south. Thus, coastal areas, especially those close to Al-Jabal Al-Akhdar and facing the wet winds receive the highest quantity of rain.

The total amount of rainfall in the region from October to March is more than 80% of the annual precipitation, evidently its maximum being in the winter; (Figure 3.3) shows that the rainy season in the study area starts in September, with an average of 4.2 mm in Derna and 4.6 mm in Al-Ftaih, and increases till it reaches the maximum in January, which is 64.2 mm in Derna and 73.9 mm in Al-Ftaih, despite a slight decline in November. Noticeably, the decrease continues from January to the end of the rainy season in June. The dry season corresponds to the emergence of spring low pressure air which is often accompanied by small amounts of rainfall during the months of April and May (Sharaf 1996). Then the rainfall fades during the summer, especially in July and August as a result of high temperature and low pressure, which are not conducive for the formation of condensation cloud, which leads to scarce of rainfall during the summer (Amqaily 1995).

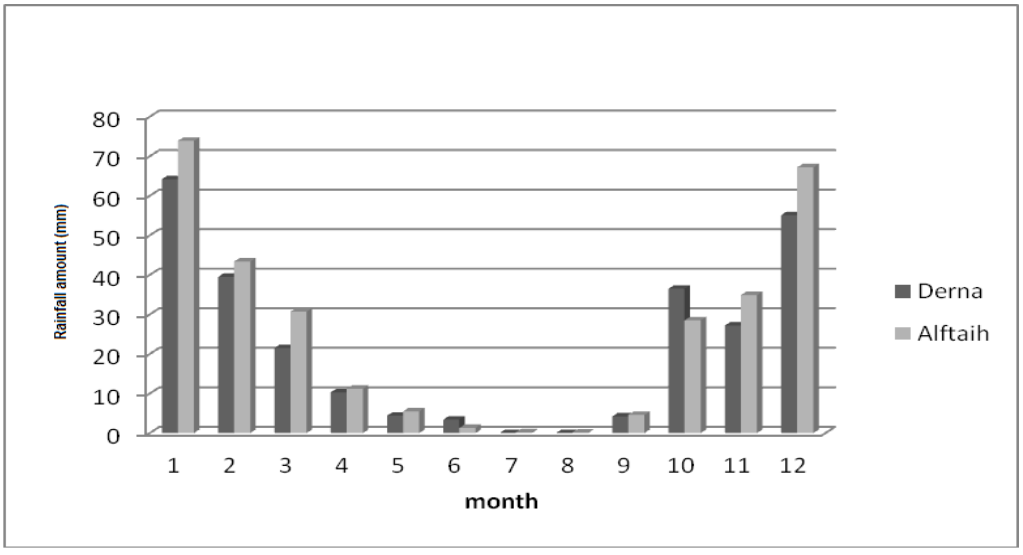

Figure 3.3 Monthly Averages of Rainfall in Derna Weather Stations and Al-Ftaih Weather Stations From (1960 – 2000)

Source: Department of meteorology

3.4.3 Relative Humidity

In general, the study area has high humidity throughout the year. The annual average is 72% in Derna and 68% in Al-Ftaih. Maximum of 77% in Derna is recorded in July, due to an increase in evaporation that comes from the high temperature during this month, which gradually decreases, due to the low temperature. The lowest rate is 60% in Al-Ftaih during May and June. The (Figure 3.4) shows significant increases during the summer months in Derna station with decrease during the months of winter in Al-Ftaih.

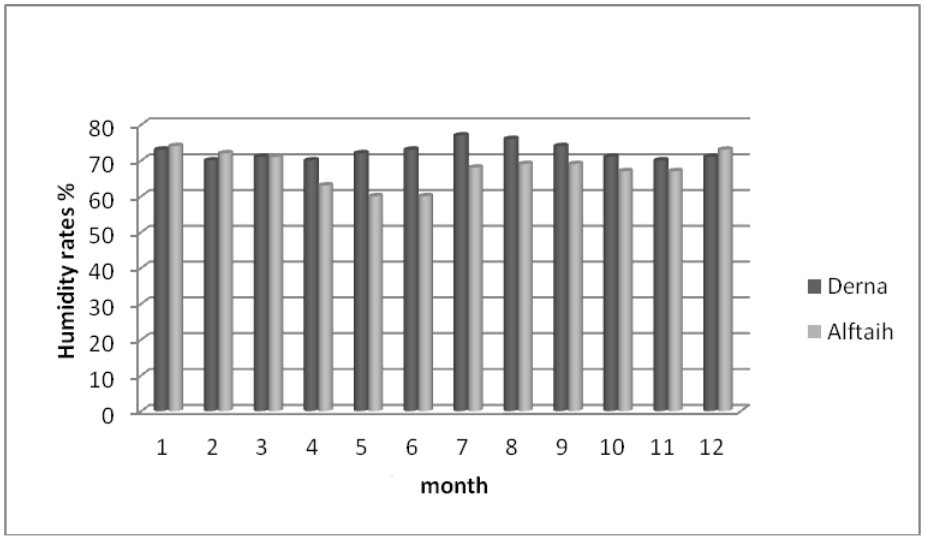

Figure 3.4: Monthly Averages of Humidity in Derna (1960-2000) and Al-Ftaih Weather Stations From (1975 – 2000)

Source: Department of meteorology

3.4.4 Air Depressions and Winds

In the study area, the air pressure is low during the summer, especially in July and August, which causes northern winds, because in this period the Mediterranean sea is the center of high pressure. But the trends of North winds are different from place to place in Al-Jabal Al-Akhdar. In Derna region the rate of northwest winds is high, which is significantly not present in other regions. It may be due to the northern edges of Al-Jabal Al-Akhdar, which changes the direction of the most of northern winds to the south-eastern trend, or because the winds in the east is more affected by a low-

pressure area on the west Asia and north- east Africa. In winter, the air pressure in November is higher than December and January and hence the cyclonic winds blow from several directions. At the same time, some short calmness periods appear when the air free depressions relaxer. The northwestern winds represent a high speed in the winter as well, because most of the permanent winds that come from Azzurri are high pressure (Malti 1995). Accordingly, the northwestern winds become the prevailing direction of winds and represent about 65% of the wind directions (Figure 3.5). As for as the wind speed is concerned, the highest speed is 21.7 km per hour in July, while the lowest speed is 14.8 km per hour in October (Figure 3.6).

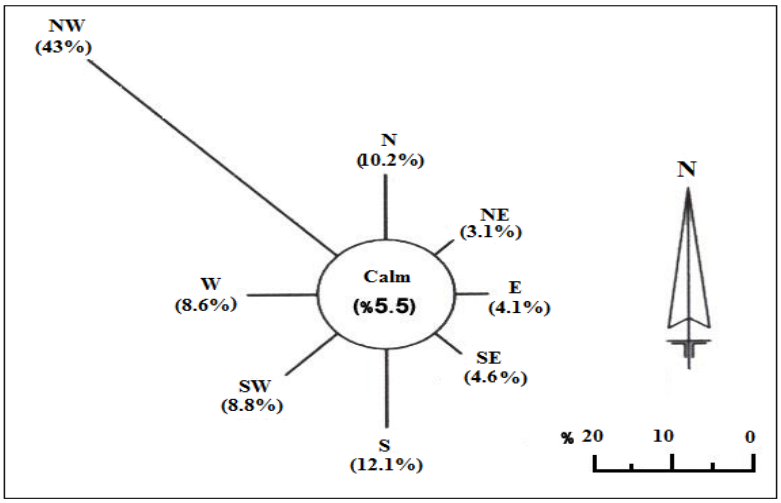

Figure 3.5 Prevailing Direction of Winds

Source: Department of meteorology

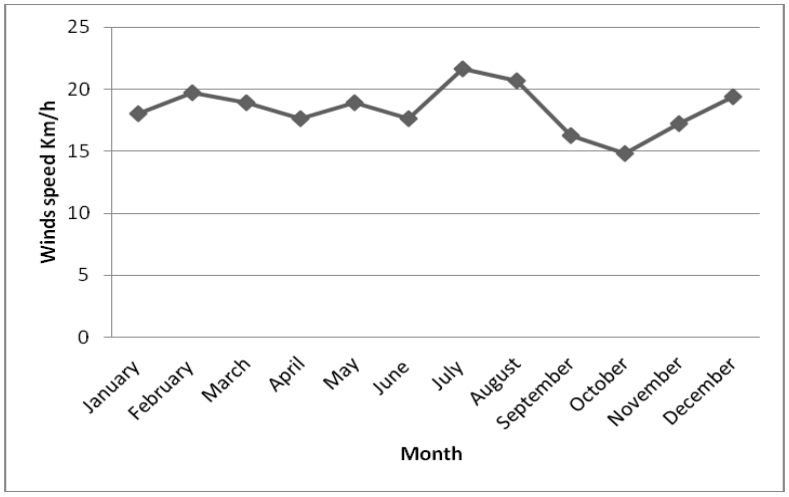

Figure 3.6 Monthly Averages of Wind Speed (Km/ h) from 1961-2000.

Source: Department of meteorology

3.5 TOPOGRAPHY

Derna region originates on a narrow coastal plain, located between the Mediterranean and the north-eastern edge of the Al-Jabal Al-Akhdar, which is characterized by severe slope towards the sea. To the south of this plain, the elevation begins to increase rapidly, which impeded growth of the city in this direction. Permeating from this region is a series of valleys of which the most important is the valley of Derna, which cuts deep into the mountain edge, and penetrates the city center to end up at the sea. However, the southern part of the region seemed to be a slightly sloped plain as shown in (Figure 3.7) (Doxiadis 1967). On the other hand, the general topography of the region slopes sharply towards the northern side though there are several local slopes in most directions.

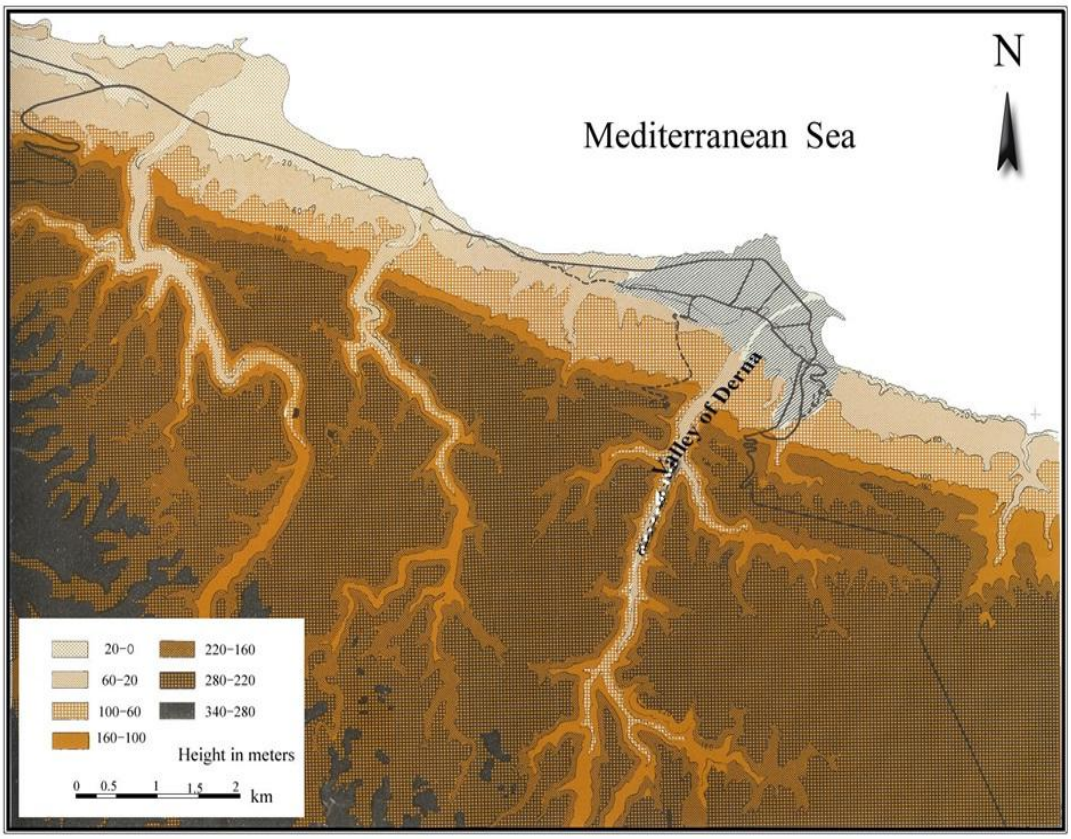

Figure 3.7 Topographic of Study Area

Source: Doxiadis 1967

3.6 SOIL

The soil in the study area is mostly within the Mediterranean red soils (Terra Rossa), which is characterized by clay content, it also contains a high proportion of iron oxide, which gives it the red color. Soil profile depth of this soil differs depending on the slope rate. The deep soil profile exists in the sediment of the valleys and plains of the first terrace of the Al-Jabal Al-Akhdar, the medium depth soils exist in slight slopes, while the shallow soils exist in steep areas with different ranges of gravel and rocks spread (Bin Mahmud 1995). These soils constitute approximately 25% of the territory of northeastern region of Libya. These soils tend to be alkaline, which constitute elements of calcium and magnesium and lesser ratio of nitrogen, organic materials, gypsum and salts; the soil has high capacity to retain the water (Bin Mahmud & Al-Gandeel 1984). (Figure 3.8) shows the soil types in the study area and the scheme of soils division into classes, and types and sub-types of the soil are illustrated in (Table 3.1).

It is worth mentioning that the soil in the region of Derna is characterized by the richness in phosphate oxide and potash, which increases the fertility. In some parts, their color tends to be light brown as a result of the use of animal manure and left over of crops residues in the soil (Boulghmh & Al-Shawi 1975).

3.7 GEOLOGY

Libya is situated on the northern periphery of the ancient African platform. The whole African continent was a part of the vast Gondwana supercontinent during the Paleozoic period. The fragmentation of the Gondwana supercontinent began in the Permian period, which had led to the development of the Tethys Ocean, of which the Mediterranean Sea is a surviving remnant. The northern part of Cyrenaica (northeastern part of Libya) was a constituent of the Tethys geosynclines, having adjoined to the platform in the course of the pine orogenesis (Bashir 2005).

Table 3.1 Soil Classification in the North East of Libya

Soil types	Soil Subtypes	Code
Brown arid soils	Brown arid differentiated soils	Bd
	Brown arid slightly differentiated soils	Bsd
Crusts	Monolithic crusts	CRm
	Non - monolithic crusts	CRnm
Siallitic cinnamon soils	Siallitic cinnamon compact soils	CScp
	Siallitic cinnamon typical soils	CSt
Reddish brown arid soils	Reddish brown arid differentiated soils	FBd
	Reddish brown arid differentiated crust soils	FBdcr
	Reddish brown arid hydromorphic crust soils	FBhcr
	Reddish brown arid non - differentiated soils	FBnd
	Reddish brown arid slightly differentiated soils	FBsd
	Reddish brown slightly differentiated crust soils	FBsdcr
Red ferrisiallitic soils	Red ferrisiallitic concretionary soils	Fc
	Red ferrisiallitic crust soils	Fcr
	Red ferrisiallitic hydromorphic soils	Fh
	Red ferrisiallitic hydrated soils	Fhd
	Red ferrisiallitic soils of a truncated profile	Fi
Lithosols	Brown lithosoils	Lb
	Cinnamonic lithosoils	Lcs
	Reddish brown lithosoils	Ltb
Rendzina	Dark rendzinas	RZ
	Red rendzinas	RZr
Saline soils and Solonchaks	Automorphic solonchaks	Sa
	Hydromorphic solonchaks	Sh
	Hydromorphic crust solonchaks	SHcr
	Hydromorphic sebkha solonchaks	SHs
Non-Soil Formations	Maritime sands	SM
Yellow ferrisiallitic soils	Yellow ferrisiallitic concretionary soils	Yc
	Yellow ferrisiallitic typical soils	Yt

Source: Bashir 2005.

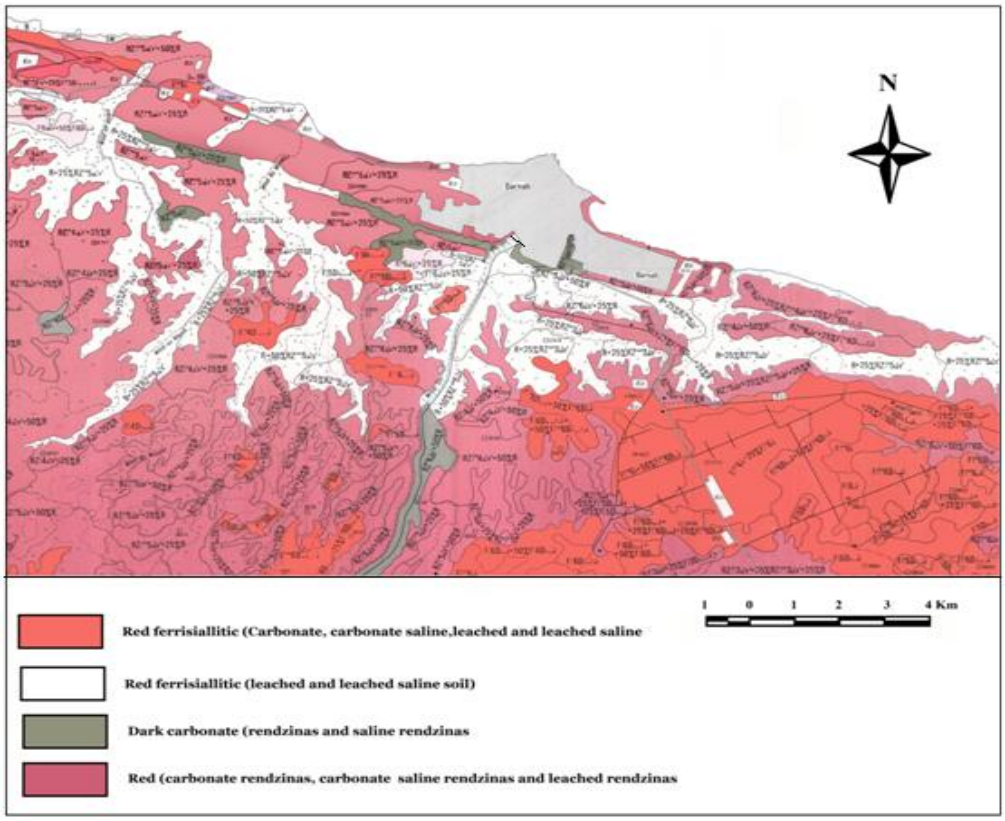
N
1 0 1 2 3 4 Km
Red ferrisiallitic (Carbonate, carbonate saline,leached and leached saline
Red ferrisiallitic (leached and leached saline soil)
Dark carbonate (rendzinas and saline rendzinas
Red (carbonate rendzinas, carbonate saline rendzinas and leached rendzinas

Figure 3.8 Soil Types in the Study Area

Source: Ministry of Agriculture 1980

In Al-Jabal Al-Akhdar region, limestone is considered as the main component of rocks, which constitutes 90% of the proportion, while the rest are marl and dolomite (Al-Arufi 1998). In the study area, the rocks dated to the tertiary and quaternary formation and are the most important formations as shown in (Figure 3.9) and the stratigraphic chart in (Figure 3.10).

3.7.1 Tertiary

a) Apollonia (Susah) Formation

This formation is considered as the oldest rocks in the study area. It can be seen not only in the visible upper part in the Bab Shiha in the south of Derna but also in the lower part of the Derna valley. The Apollonia Formation is represented by a coarse-grained microscopic crystalline limestone. The formation has pale gray and white light color in some parts and relatively pure, chalky in other parts. The formation originsed

from the deep-sea deposits, and contains tubers and dark brown layers of flint, that distinguishes it from a Derna formation. The transition zone between these two formations seems to be relatively a little thick (Al-Mansoury 1996).

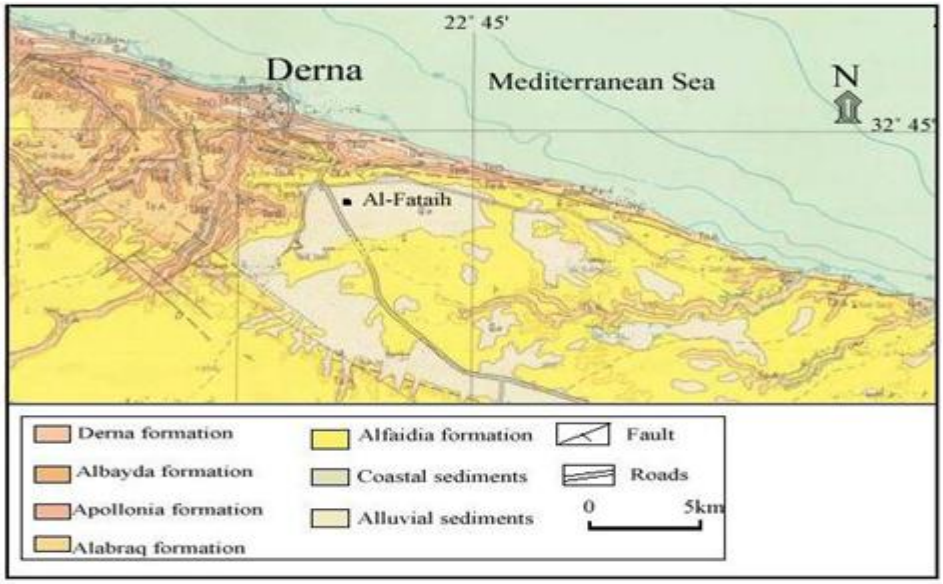

Figure 3.9 Geological Map of Derna Region

Source: Industrial Research Center 1974

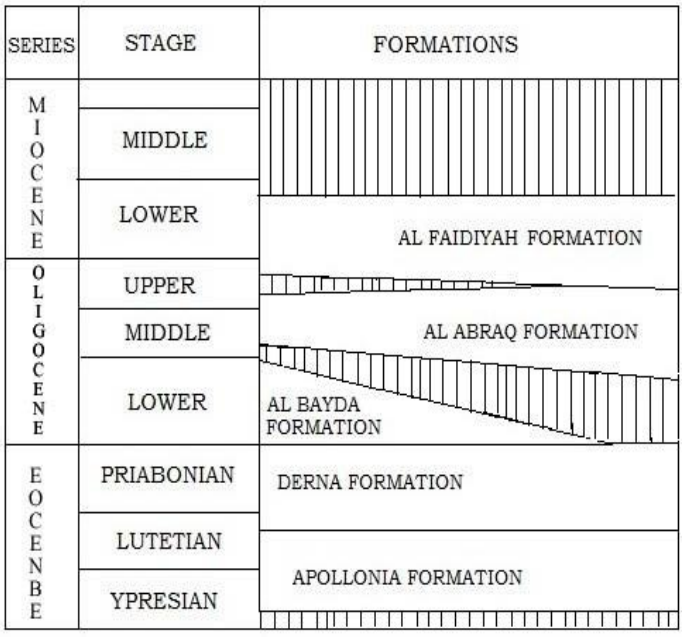

Figure 3.10 Stratigraphic Sequences of the Region

Source: Industrial Research Center 1974

b) Derna Formation

In the lower part of this formation, the rocks consist of a coherent medium to coarse grained solid layer of light gray limestone and dolomite limestone. The development in the central and upper parts of this formation indicates that there were favorable conditions for reef growth. The reefs contain dominant algal limestone with some layers rich in solitary corals and at places they grade into coral limestones. Stratigraphically, it coincides with the Lower Priabonian. These sediments suggest a continual rhythmical shallow of the sedimentation area and a beginning of the reefoid sedimentation (Industrial Research Center 1974).

c) Al-Bayda Formation

This formation represents the stratigraphic sequences to the lower Oligocene, where the formation of reef sedimentation continued until this age. The Al-Bayda formation appears in the form of algal limestone and the colour is yellow tends to white. It contains a large amount of Priabonian rocks, which has been deposited during the lower Oligocene**.** The Shahat Marl Member is the most important component of this formation with a high proportion of yellowish marl. The rock cycle of Al- Bayda, gradually disappears towards of the east (Al-Mansoury 1996).

d) Al-Abraq Formation

This formation also represents the stratigraphic sequences for Oligocene. It is a single sedimentation cycle, and it is above Al- Bayda formation. However, it does not appear in the region such as Apollonia and Derna formations. This formation is characterized by the presence of brown Calcarenites and Calcilutites with a few overlaps of the limestone, which consist fossils and algae. Often the sedimentations of this formation are characterized by the presence of dolomitic (Industrial Research Center 1974).

e) Al-Faidiya Formation

From a broader regional point of view, it is evident that this formation is from the marine immersion of east and south of Al-Jabal Al-Akhdar which has attained its maximum in the Lower Miocene. It represents the youngest and last marine

sedimentation in the eastern part of Al-Jabal Al-Akhdar. Fossil studies have shown that the Al-Faidiya formation stratigraphically ranges from the Upper Oligocene to the Lower Miocene. The maximum thickness of the Derna region apparently does not exceed 140 -150 meters. There is a clayey horizon at the formation base. In the north-western part of the region it assumes the character of greenish gray calcareous clay, with an irregularly developed bed of gray marl containing glauconite grains, limestone is also found in the upward direction. It is whitish, mostly fossiliferous or organodetrital, rich in macrofauna (Industrial Research Center 1974).

3.7.2 Quaternary Sediments

Quaternary formations strictly do not appear as form layers, in this period as compared with the rest of the formations. Its sediments are spread along the Mediterranean coast in the form of beach sands (Industrial Research Center1974). Furthermore, the deposits of the region consist of boulders, gravels and sands, these sediments are characterized by their thicknesses, especially at the estuary of the valleys, and create floodplain (Al-Harram 1997). The extension of quaternary sediments is limited, and they can be classified into four type comprising eolian deposits, litteral marine deposits, lagoonal deposits and alluvial deposits (Hamad 2008).

3.8 WATER RESOURCES IN THE REGION

Water is the main source for life, where humans history and civilizations are closely correlated with the availability of this source and use it (Al-Mahdawi 1998). It is worth mentioning that, the study area is one of Al-Jabal Al-Akhdar's regions that are characterized by an abundance of water resources. Derna valley is a deep valley as a result of water, and it is considered an important source of water. The water is available in the form of springs and wells (Al-Mansoury 1996).

3.8.1 Water Sources

Water is considered as the most important pillars of economic life, especially when

agriculture is an important part of life. Libya lacks of permanent waterways due to the oscillation of rainfall patterns and the nature of the geological formation of the country, hence the groundwater is considered the main water source. Therefore is crucial to preserve the groundwater and search for other sources of water to meet the continuing needs of water, due to the population growth and ever-increasing urban development (Boulghmh 1975).

a) **Groundwater**

As a result of the low precipitation in Libya, groundwater resources have been utilized as the main source of domestic, agricultural and industrial use. Rapid urbanization, economic and population growth coupled with improvement in the standard of living along the coastal strip in the northern part of the country have created an increasing demand on groundwater resources. Thus, the groundwater resources are exposed to increased risk due to the intensive and continuous use, which in turn results in reducing the water level and increases the sea water intrusion into the coastal aquifer. Therefore, the groundwater in the coastal regions is over exploited in not sustainable manner. The groundwater level will continue decline which may lead to dangerous situations (El-Asswad 1995; Bindra et al. 2003; Bashir 2005). In spite of that rainwater is the main source of recharging groundwater, huge quantity of this water is lost without giving benefit, either by evaporation or flowing directly into the sea. Some studies have revealed that the rate of leakage of water towards the groundwater reservoirs in the region does not exceed 20% of rainfall water. Accordingly, dams are constructed in the region for the purpose of recharging the aquifer, to protect the city from the dangers of floods, and to increase the productivity of integrated agricultural project (Al-Mansoury 1996). The groundwater sources in the study area include the following:

I. Spring Water

Springs are the most reliable and important water sources in the region for all human uses, and these springs are:

a. Spring of Al-Belad: its water comes from the limestone layers of the Middle Eocene. It is located at a height of 60 meters above sea level on the west bank of the Derna valley, and about 5.5 km from the coastal line (Jawda 1998). It is the main source which supplies the water needs of the city. The production of water ranges between 40-100 l/s (Ismail 1998).

b. Spring of Abu-Mansour: it is also located in the Derna valley basin, at a distance of 12 km from the sea, the water flows from the underground water level in the layers of Lower Oligocene (Jawda 1998). It is at a height of 160 meters above the sea level, and produces between 120-250 l/s daily. Its water moves towards the north through the channel on the east bank of the valley (Ismail 1998).

II. Wells Water

The constant increase in population growth, urban development and other human activities have resulted in the huge demand for water; hence it has become crucial to search for water sources, and therefore ten wells were drilled in the period between 1961-1976 and the productivity at the time ranged between 175 - 2700 m^3 / day, later three more wells were drilled, which produced between 240-300 m^3 / day. During 1993 - 1994 ten new wells were drilled in the same area with an average production capacity of 20 l/s. These wells have greatly helped to relieve the water demand. In the Al-Maghar district (west of the region) three wells had been drilled in addition to two ancient wells, and four other wells were drilled in the Abu-Mansour (south of the study area). In the late nineties another well was drilled in Abu-Mansour and fourteen other wells in Al-Sahil (east of the study area) to make up a severe shortage of water. At the end of the nineties, Al-Maghar had 12 active wells and their production range between 13-20 l/s, and total production was together about 162 l/s. In the west of the region, there are five wells, two of them produce approximately 30 l/s, in Abu-Mansour, there are four wells, of which two of them produce about 32 l/s. Later a series of wells were drilled across the region and hence the total number of wells became 64, of which more than 16 have been closed due to the breakdown of pumps or contamination of water and they are not suitable for human use (Ismail 1998). The depths of the wells in the region vary from one place to the other. The depth in the

valley of Derna is about 65 meters, and it is the lowest in the region. The depth of wells increases slightly in the range of 110 to 120 meters, 100 to 160 meters and 120 to 178 meters in the neighborhood of Assalam (the western coast), Bab Shiha and Bab Tobruk (Abu-Mansour) respectively in the north and northwestern parts of the study area. However, in Al-Ftaih area (south and southeastern parts of the region) the depth increases rapidly and ranges from 320 to 350 meters (G.W.C 2010). This variation maybe is due to the variation of elevation of the topography.

b) Desalinated Water

Due to the severe shortage in the availability of drinking water in recent times, it was decided to use sea water to meet water needs of the region through the establishment of two desalination plants:

a. Abu-Msafir plant: it is located near the Valley of Abu-Msafir 6 km west, and consists of 2 units, which produces 4600 m3 of water per day. Of which 4000 m3 of water is pumped to major reservoirs in Al-Maghar to contribute towards the needs of drinking water in the city, while the remaining quantity is allocated to the needs of the plant.

b. Munqar Rabeh plant: it is about 60 Km south- east the city and consists of 3 units to produce about 30000 m3 of water per day, in 1994 about 10000 m3 of water per day daily was pumped to major reservoir in Al-Sahil, which has significantly contributed to solve the problem of water shortage in that region (Elgali 2006).

3.8.2 Water Consumption

Derna region gets most of its water supply for urban use from the spring of Al-Belad, Al-Ftaih's well fields and Bab Shaiha's well fields. The actual production is up to about 3,504,000 m^3 per year. However, some of the existing fields of drinking water are suffering from heavy deterioration of its quality, for instance Bab Shaiha's wells field and wells of Al-Sahil area, and are mostly unfit for drinking (G.W.A 2006). The available daily consumption in the region is about 1600 cubic meters approximately

(200 liter per person per day). The required consumption is about 20000 cubic meters per day (250 liter per person per day). The amount of water shortage in 2006 was 4000 cubic meters (Bin Imran et al. No date). As illustrated in (Figure 3.11) in the context of water consumption by sectors of the region, 66% of the available water is consumed for the domestic sector, 24.6% for agricultural sector, 4.8% for industrial sector and 3.6% for the municipal sector.

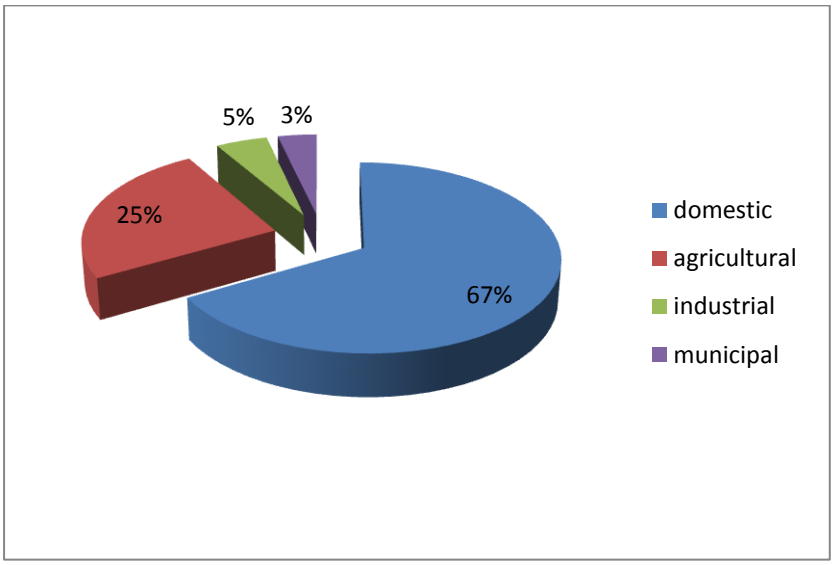

Figure 3.11 Water Consumption Distributed to the Various Sectors in the Region

Source: Bin Imran et al.

3.9 POPULATION GROWTH IN THE STUDY AREA

The general trend of the evolution of population growth is the result of those changes in natural and non-natural circumstances. Therefore, by taking a look at these changes, it is evident that the population growth in Libya in general and in Derna in particular, is a kind of rapid increase as in the case of most developing countries (Al-Kekhia 1995).

The trend of population growth in Derna is not static. Between 1954 to 1964 it was 2.9%, and increased to 5.9% in the period from 1964 to 1973; then the rate began to go down to 4.4% from 1973 to 1984, and this trend continued until it reached 1.6% in the period from 1984 to 1995, while in the period from 1995 to 2006 the rate increased slightly and reached 2.9%, which suggests that the population growth in the

city is characterized by instability (Table 3.2). This rise in growth rates is due to the significant changes in the economic base and industrial growth, in addition to the importance of the city as a cultural and tourist center, as well as the existence of some urban ingredients. Improvement in the health and living conditions, especially in the seventies has made the city to become a center of attraction for the residents. Also some kind of migrations and high cultural and educational level of the population in recent times have led to the decrease in the rate of growth once again (Boukhchame 1979).

Table 3.2 Census and Growth of Population in Libya and Derna Region from 1954 to 2006.

The years	Population of Libya	Growth rate	Population of Derna	Growth rate
1954	1,088,873	#	15,891	#
1964	1,564,369	3.6%	21,401	2.9 %
1973	2,249,237	3.9%	37,051	5.9 %
1984	3,642,576	4.3%	60,981	4.4 %
1995	4,799,065	2.5%	72,690	1.6 %
2006	5,657,692	1.4%	83,857	1.3 %

Source: National Authority for Information and Documentation 1954,1964, 1973,1984,1995,2006.

3.9 CONCLUSION

This chapter had given a brief description of the study's region. It had offered a brief historical overview of the region and discussed its natural characteristics such as, the geographic location, climate, topography, soil, geology and the water resources. On the other hand, this chapter had explained the population growth in the region. The following chapter will explain the methodology of the study to illustrate the data collection and analysis processes.

CHAPTER IV

RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter discusses method of the study. As the objective of this study is to provide information on the characteristics of groundwater quality and run spatial analysis and analysis of groundwater pollution in the region of Derna (the north-eastern part of Libya), hence the study used the methodology as illustrated in (Figure 4.1) and (Table 4.1).

4.2 DATA COLLECTION STAGE

4.2.1 Literature Research

In this stage of the research the information and data that are related to the topic of study were gathered from books, Journals, thesis and scientific researches. Furthermore, the population statistics and comprehensive plan for the study region has been carried out. In additional the climatic data for the climatic period from 1961 to 2000 was also collected from the meteorological Stations of Derna at the altitude of 26 meters, and Al-Ftaih at altitude of 250 meters above the sea level.

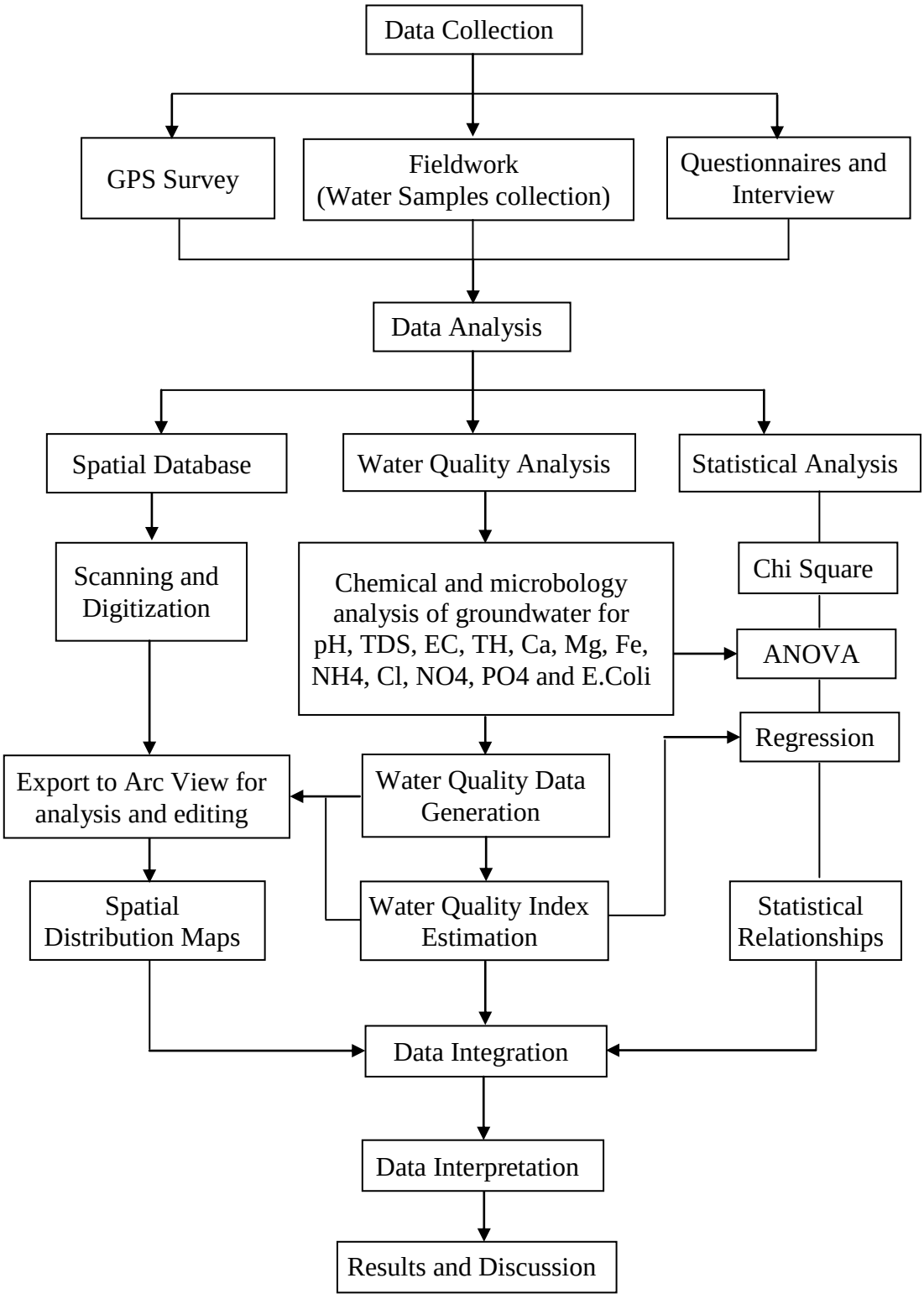

Figure 4.1 the Conceptual Framework of the Methodology

Table 4.1 Data Collection and Analysis

#	Objectives	Data Collection	Data Analysis
1	Factors leading to contamination	Questionnaire and Water samples	Chi square, ANOVA and Laboratory analysis
2	Water quality distribution	Water samples, parameters and GPS	GIS
3	Water suitability for human use	Water samples and parameters	WQI and Regression

4.2.2 Field Study

In the next stage a field study was conducted to obtain data for the study and which is difficult to get from the literature research source. Comprehensive questionnaires were designed; containing a series of questions related to the subject of study and was directed to users of groundwater wells (appendix A). The questionnaires were distributed to a sample of the residents of the region of study in both, urban and rural sections. The study society included families living in all the parts of the study area (Al-Maghar, Al-Belad, Al-Jubaila, Abu-Mansour, Al- Sahil and Al-Ftaih), which contains about 15483 families (National Authority of Information and Documentation) 2006). Personal meetings with specialized and authorized persons in the General Company of Water and the General Authority of Water were conducted.

a) Sampling Size

In principle, there are three factors that determine the sample size namely; standard deviation, standard error and tolerable error see (Equation 4.1) (Abd Rahim 2009).

$$n = \left[\frac{Z\,\sigma}{E}\right]^2 \quad \text{.....(4.1)}$$

Where:

$$n = Sample\ size$$

$$Z = Standard\ Error$$

$$\sigma = Standard\ Deviation$$

$$E = Tolerable\ Error$$

To determine the size of the sample, firstly the standard deviation of certain characteristics of the residents living in the study area has to be determined. Monthly income would be a suitable variable to represent the general characteristics of the residents. In the beginning about 50 questionnaires were distributed randomly as a pilot study, where it was significantly responded by them, given the ease and comprehensiveness the questions which conformed to most classes of the society. Accordingly, the standard deviation of monthly income of the respondents has been identified to be Libyan Dinar 255, the tolerable error was set at Libyan Dinar 20, and the standard error has been chosen at 1.65 at a significance level is 0.10, (Equation 4.2) shows the appropriate sample size.

$$n = \left[\frac{Z\,\sigma}{E}\right]^2 \quad \text{.....(4.2)}$$

$$n = \left[\frac{(1.65)(255)}{20}\right]^2 = 442.6 \cong 443$$

This is however the minimum sample size calculator; the exact figure was raised to 450 persons, who have been interviewed including on the pilot study mentioned above.

b) Sampling Technique

The sampling technique has been carried out through the Stratified Relative Sample; where the sampled society was divided into 6 layers (Al-Maghar, Al-Belad, Al-Jubaila, Abu-Mansour, Al-Sahil and Al-Ftaih), and then the sample units of each layer have

been chosen depending on its size by the Simple Random Sample. Where it gives more accurate estimates than the other samples, because the size of each layer determines the size of the sample, this means we have taken a number of units that are proportionate with the size of each layer (El-Saleh & El-Seriani 1979). Based on this, the sample has been distributed to the layers of the study society by the following:

(1) Proportion of each layer of the sample size =

$$\frac{\text{Number famileis in each part}}{\text{Total number of families (study society)}} \times 100$$

(2) The share of each layer of the sample size =

$$\frac{\text{Proportion of each layer of the sample size}}{100} \times \text{sample size}$$

Al-Maghar: (1) = $\frac{4661}{15483} \times 100 = 30.1\%$

(2) = $\frac{30}{100} \times 450 = 135.4$ respondents

Al-Belad: (1) = $\frac{450}{15483} \times 100 = 2.9\%$

(2) = $\frac{2.9}{100} \times 450 = 13$ respondents

Al-Jubaila: (1) = $\frac{3471}{15483} \times 100 = 22.4\%$

(2) = $\frac{22.4}{100} \times 450 = 101$ respondents

Abu-Mansour: (1) = $\frac{2906}{15483} \times 100 = 18.8\%$

(2) = $\frac{18.8}{100} \times 450 = 85$ respondents

Al-Sahil: (1) = $\frac{3320}{15483} \times 100 = 21.4\%$

(2) = $\frac{21.4}{100} \times 450 = 96$ respondents

Al-Ftaih: (1) = $\frac{685}{15483} \times 100 = 4.4\%$

(2) = $\frac{4.4}{100} \times 450 = 20$ respondents

The share of each layer of the sample size has been arranged as in (Table 4.2). After that, the sample sites were identified (selected families) by the random sample in each section in the region of the study area and distributed all the 450 questionnaires.

Table 4.2 the Distribution of Sample Units Into Layers of the Study Area

No	Layer Name	Families Number	Percentage	Number of Selected Respondents
1	Al-Maghar	4661	30.1%	135
2	Al-Belad	450	02.9%	13
3	Al- Jubaila	3471	22.4%	101
4	Abu-Mansour	2906	18.8%	85
5	Al-Sahil	3320	21.4%	96
6	Al-Ftaih	685	04.4%	20
	Total	15483	100%	450

Source: Field work 2010

c) Water Samples Collection

In order to evaluate the suitability of groundwater for human use in the Derna region, most of groundwater sources (wells and springs) had been taken into account. The coordinates and elevations of samples locations were carried out using the Global Positioning System (GPS) survey. A total of thirty-one water samples (twenty-nine wells and two springs) were collected in sample bottles from the selected locations, throughout the study area as illustrated in (Figure 4.2). Army map service (1:250,000) of the region of Derna was used as basic information for the GIS database. The coordinates and altitude values of the selected sampling locations are given in (Table 4.3).

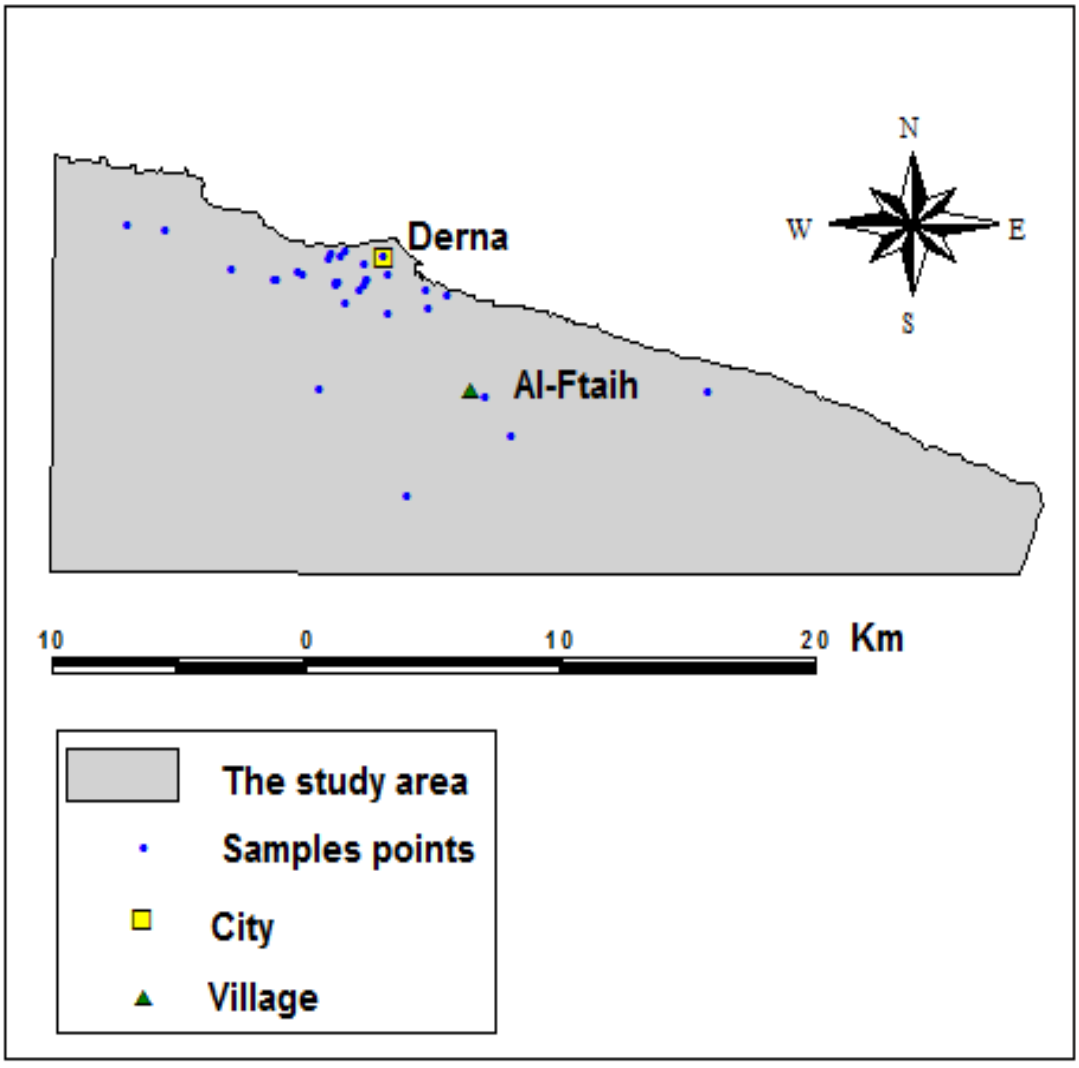

Figure 4.2 Map Showing the Location of Sampling Points

Table 4. 3 Coordinates and Elevation of Samples

No	Sample Location	Source	Latitude (N)	Longitude (E)	Altitude/m
1	Al-Maghar	Well	32 45 56	22 36 45	58.5
2	Al-Maghar	Well	32 46 11	22 35 09	43.9
3	Al-Maghar	Well	32 45 33	22 37 42	72.2
4	Al-Maghar	Well	32 45 35	22 37 44	81.1
5	Al-Maghar	Well	32 45 35	22 37 42	87.8
6	Al-Maghar	Well	32 45 47	22 36 14	93.6
7	Al-Maghar	Well	32 45 49	22 36 08	98.5
8	Al-Maghar	Well	32 45 51	22 36 52	66.1
9	Abu-Msafir	Well	32 47 31	22 32 45	20.1
10	Abu-Msafir	Well	32 47 17	22 33 42	6.1
11	Al-Belad	Well	32 45 58	22 38 25	12.2
12	Al-Belad	Well	32 46 04	22 38 54	8.8
13	Al-Jubaila	Well	32 46 11	22 37 51	12.8
14	Al-Jubaila	Well	32 46 16	22 37 39	11.9
15	Al-Jubaila	Well	32 46 09	22 37 37	13.1
16	Al-Jubaila	Well	32 46 17	22 38 03	8.8
17	Abu-Mansour	Well	32 45 39	22 39 02	11.3
18	Abu-Mansour	Well	32 45 38	22 38 52	28
19	Abu-Mansour	Well	32 45 19	22 38 14	72
20	Abu-Mansour	Well	32 45 32	22 38 27	58.8
21	Abu-Mansour	Well	32 45 28	22 38 21	56.7
22	Abu-Mansour	Well	32 45 32	22 38 29	61.3
23	Al-Sahil	Well	32 44 41	22 39 52	93
24	Al-Sahil	Well	32 45 06	22 39 50	49.4
25	Al-Sahil	Well	32 45 00	22 40 22	48.8
26	Al-Ftaih	Well	32 40 17	22 38 38	270.1
27	Al-Ftaih	Well	32 41 58	22 46 26	224.6
28	Al-Ftaih	Well	32 42 28	22 40 54	245.1
29	Al-Ftaih	Well	32 41 25	22 41 24	254.5
30	Al-Belad spring	Spring	32 45 03	22 37 48	50.3
31	Abu-Mansour spring	Spring	32 43 06	22 36 54	94.8

Source: field work

4.3. DATA ANALYSIS STAGE

After the completion of the data collection stage; the process of data analysis was carried out to get results. The Central Laboratory of Water in the General Company of Water was relied upon for the chemical and microbiological analysis of collected water sample. The results were later compared to global and Libyan standard water specifications.

4.3.1 Laboratory Analysis

In the Central Laboratory, water analysis has been carried out by measuring the concentration of a standard set of constituents including: pH, Electric Conductivity (EC), Total Dissolved Solids (T.D.S), as well as Total Hardness(T.H), Calcium (Ca++), Magnesium(Mg++), Iron(Fe), Ammonia(NH_4), Chlorides(C1), Nitrite(NO_2), Phosphate (PO_4), as well as bacterial analysis (E. coli).

4.3.2 Statistical Analysis

The Statistical Package for Social Science program (SPSS) (Figure 4.3) was employed to analyze the statistical data and to convert them into tables, percentages and graphics, to link reasons and the results obtained. Chi square was used to determine the possibility of an association between the changes of groundwater quality and some water pollution sources. The one-way ANOVA (analysis of variance) was used as well, in order to examine the mean differences in E. coli count in thirty-one groundwater samples and its extent of spread among the sections of the region. On the other hand, Multiple Linear Regression (MLR) was applied to identify the relationship between the water quality parameters and their impact on WQI. The model of MLR takes the following form (Equation 4.3), (Abd Rahim 2009):

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + ...b_nx_n + e_i \quad \text{.....(4.3)}$$

Where:

Y = the dependent variable.

x_1 to x_n = the independent variables.

a = constant.

e_i = the error or residuals.

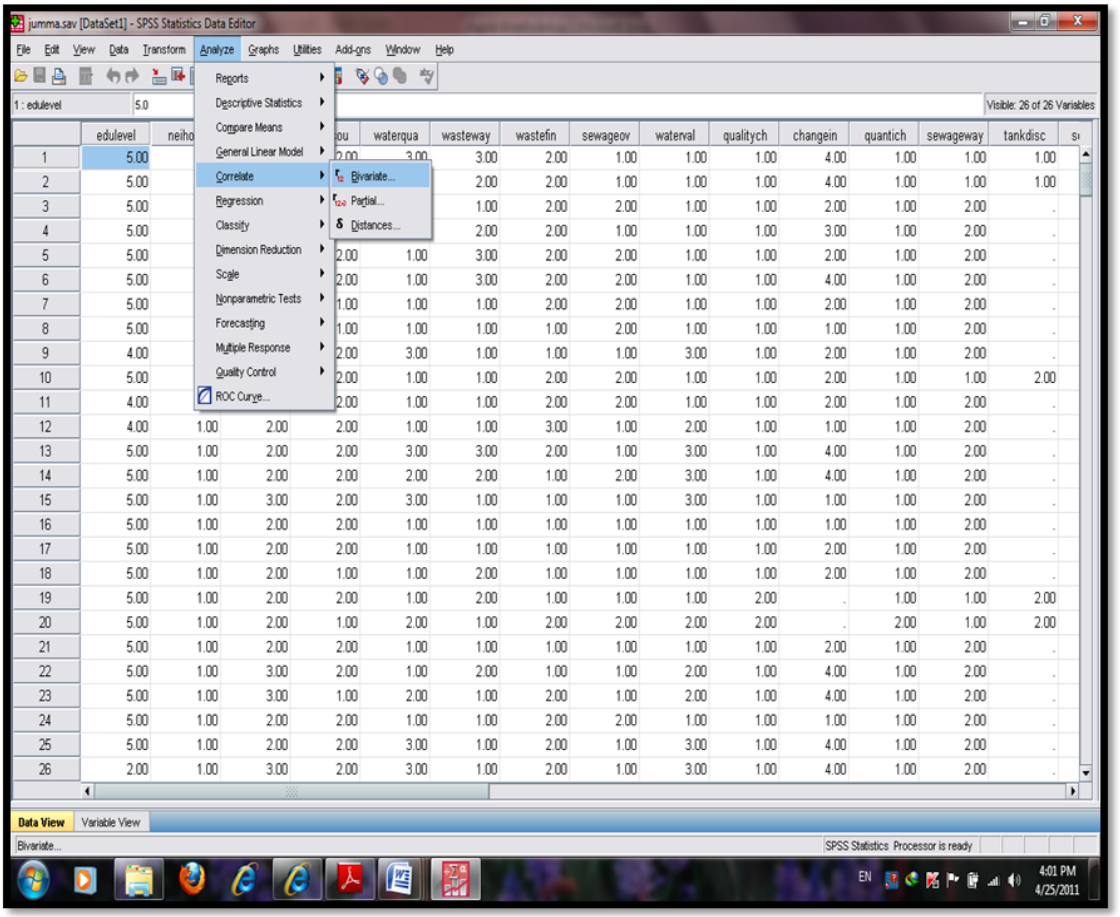

Figure 4.3 the Statistical Data Analysis

4.3.3 Geographic Information System (GIS) Analysis

Arc View software in GIS approach (Figure 4.4), was employed as a tool for producing the maps of the spatial distribution of concentrations of the groundwater contamination sources. The samples coordinates were converted to meters using Franson CoordTrans software to be suitable with Arc View technique. The map of the Derna region on 1:250,000 scale was scanned and set up with thirty-one groundwater samples. The location points of the wells were digitized and the corresponding location numbers were assigned. The

water quality data obtained formed the attribute database, and it was stored in excel format and was converted into d-base file (dbf), to transport the data to arc view project, and then it was linked with the spatial data by join option in Arc View. The spatial and the attribute database formed are integrated for the generation of spatial distribution maps of the water quality parameters. In the present study the spatial interpolation technique through Inverse Distance Weighted (IDW) approach in GIS has been used to delineate the spatial distribution of groundwater contaminants. The IDW method uses a selected group of sample points for estimating the output grid cell value. It determines the cell values using a linearly weighted collection of a set of sample points and controls the significance of known points upon the interpolated values according to their distance from the output point. These are the procedures needed to generate a surface grid as well as thematic isolines (Asadil et al. 2007).

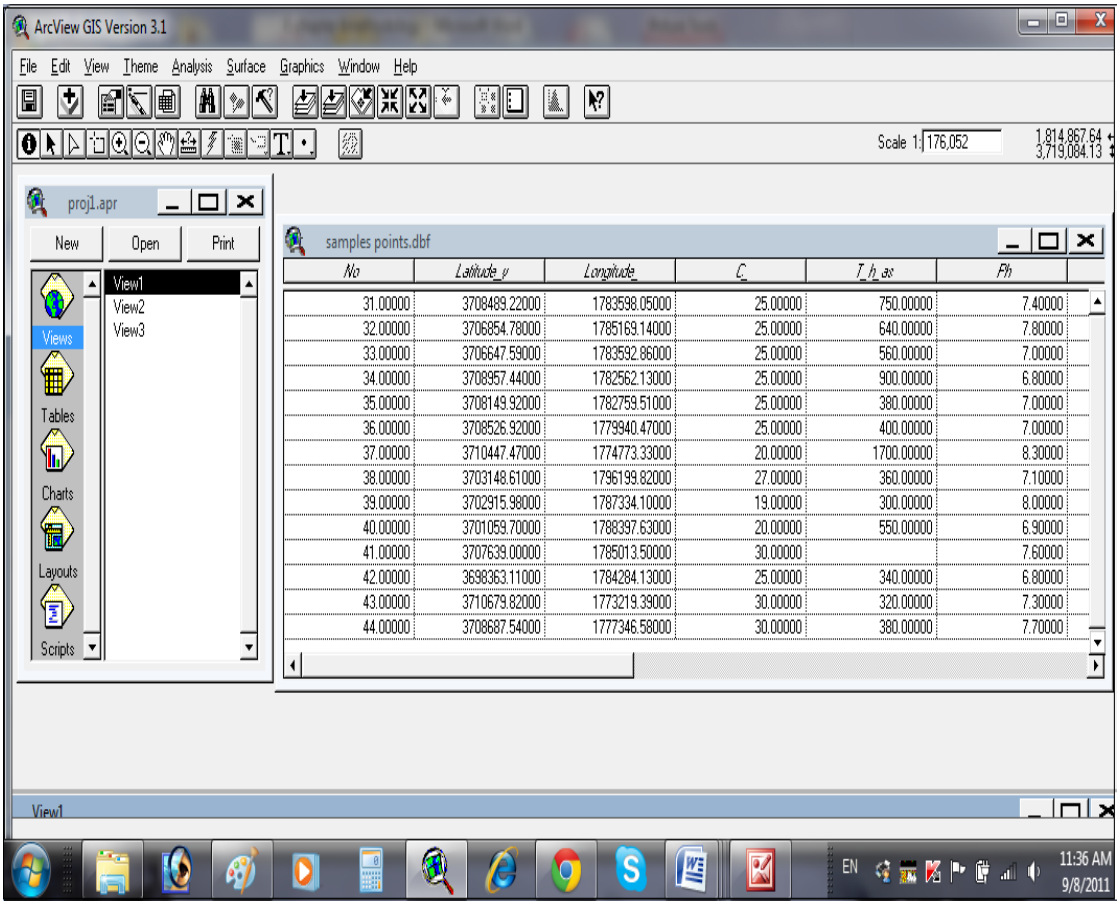

Figure 4.4 the Arc View Software in Geographic Information System

4.3.4 Water Quality Index (WQI)

Pollution status was estimated using Water Quality Index (WQI). The WQI for groundwater in Derna region was determined in order to assess the suitability of water for consumption by considering eleven important chemical and biological parameters, namely pH, Total Dissolved Salts (TDS), Total Hardness as Ca Co3 (TH), Calcium (Ca++) Magnesium (Mg++), Iron (Fe), Chlorides (Cl), Phosphate (PO4) and E. coli.

WQI calculation was done according on the following steps:

I. Unit of weight (Wi):

Unit of weight means the relative significance of each water quality factor based on the standard (desirable) limits in drinking water. Parameters that have lower permissible limits are more harmful to the water quality, so weightage of the factors has an inverse relationship with its permissible limits. On the other hand factors which have higher permissible limits have low weightings. (Equation 4.4) shows the the calculated weightage (Wi) of all the factors (Table 4.4), (Nair et al. 2006; Ashwani & Anish 2009):

$$Wi \propto \frac{1}{Vi} \; or \; Wi = \frac{K}{Vi} \quad \text{..... (4.4)}$$

Where:

Wi = Unit weight of the factor.

Vi = Standard (desirable) limits.

K = Constant of proportionality.

The value of ‘K’ was calculated as the following (Equation 4.5):

$$K = \frac{1}{\sum_{i=1}^{9} \frac{1}{Vi}} \quad \text{..... (4.5)}$$

Where:

$$\sum_{i=1}^{9} \frac{1}{Vi} = \frac{1}{Vi(pH)} + \frac{1}{Vi(TDS)} + \frac{1}{Vi(TH)} + \frac{1}{Vi(Ca)} + \frac{1}{Vi(Mg)} + \frac{1}{Vi(Fe)} + \frac{1}{Vi(\mathrm{Cl})} + \frac{1}{Vi(Po2)} + \frac{1}{Vi(E.coli)}$$

Table 4.4 Water Quality Parameters, Standards and Assigned Unit Weights

Water quality Parameters	Standards (Desirable) limits (Vi)*	Unit weights (Wi)
PH	7.0-8.5	0.00867
TDS	<1000	0.0000737
TH	< 500	0.000147
Ca++	<200	0.0003685
Mg++	<150	0.000491
Fe	< 0.30	0.2456
Cl	<250	0.0002948
Po4	<0.1	0.737
E. coli	<10	0.00737

***** The National Center for Standards Specification, Libya1993

II. Rating scale (Vr):

In connection with a rating scale, all water quality factors had been assigned a rating value (Vr) to calculate the WQI. The rating scale values range between 0 and 100, and have been divided into five categories, to assign rating value to a factor (Table 4.5). The rating Vr = 0 implies that, the parameter has exceeded the standard (desirable) limit and water is heavily contaminated, whereas Vr = 100 implies that the parameter in water has the most desirable value and the water is clean. The other rates among the highest and lowest value are Vr = 40, Vr = 60 and Vr = 80 representing intermediate conditions of water and the water is severely polluted, moderately polluted and slightly less polluted respectively (Nair et al. 2006; Ashwani & Anish 2009).

Table 4.5 Rating Scale Values to Calculate WQI

Parameters	**Ratings**				
PH	7.0-8.5	8.6 – 8.7 6.8 – 6.9	8.8-8.9 6.7-6.8	9.0-9.2 6.5-6.7	> 9.2 < 6.5
TDS	0-250	251-500	501-750	751-1000	>1000
TH	0-125	126-250	251-375	376-500	> 500
Ca++	0-50	51-100	101-150	151-200	>200
Mg++	0-37.5	38-75	75.5-112.5	113-150	>150
Fe	0-0.07	0.08-0.14	0.15-0.21	0.22-0.30	> 0.30
NH4	0-125	0.126-0.250	0.251-0.375	0.376-0.5	>0.5
Cl	0-62.5	63-125	125.5-187.5	188-250	>250
NO2	0-0.25	0.26-0.5	0.51-0.75	0.76-1	>1
PO4	0-0.025	0.026-0.05	0.051-0.075	0.076-0.1	>0.1
E. coli	0-2	3-5	6-8	9-10	>10
Ratings (Vr)	100	80	60	40	0
Extent of Pollution	Clean	Slight Pollution	Moderate Pollution	Excess Pollution	Severe Pollution

III. Water Quality Index Calculation

WQI is a compilation of a number of all parameters that can be used to determine the overall quality of the groundwater under study (Ashwani & Anish 2009). It is basically a mathematical means of calculating a single value from multiple test results, to give the level of groundwater quality in the region.

The values of the rating scale (Vr) and unit weights (Wi) of all 7 parameters were determined. And thus, by multiplying Wi and Vr, we can get the value of WQI based on (Equation 4.6).

$$\mathrm{WQI} = \sum(\mathrm{Wi} \times \mathrm{Vr}) \quad \text{..... (4.6)}$$

CHAPTER V

GROUNDWATER POLLUTION SOURCES AND ITS PROPERTIES

5.1 INTRODUCTION

This chapter discusses about natural and human groundwater pollution sources in Derna region. The natural sources depend on the nature and type of the soil sediment and rock, through which the groundwater moves and affects the quality of the recharge water. While, the human sources constitute different human activities. Chi-square has been applied to find relationships between the quality of groundwater and sources of contamination. Furthermore, this chapter also discusses the chemical and bacterial characteristics of groundwater in the study area, and compares of means of groundwater parameter concentrations among the sections of the region by applying the one way Analysis of Variance (ANOVA).

In the past, people believed that the soil, sediment and rock layers that cover the aquifer acted as natural filter which kept away many unnatural pollutants from the surface and prevent them from leaking down to groundwater. However by the 1970s, it was widely understood that, those layers often do not adequately protect aquifers. Nevertheless, even after this knowledge, significant amounts of pollutants had been already released to the soil and groundwater. Scientists have realized that, once an aquifer becomes polluted, it may become not usable for decades, and consequently the cleaning up operation is time consuming and expensive activity (William 2010). Negative contamination effects on water resource, except the salinity problem were limited in the past. In recent times, increase of population and different human activities have led to negative changes in quality and quantity of water resource, particularly the groundwater, which have resulted from increased demand of water ,

furthermore the above mentioned activities have affected the absorptive capacity of ecosystems. Water pollution in general and groundwater in particular is considered as one of most significant environmental problems that have escalated with the increase in human activities and misuse of water resources.

Groundwater pollution is considered as the most serious problem due to its negative impact on health and the environment (Al-Taira 2004). Groundwater pollution is "any substance that, when it reaches an aquifer, makes the water unclean or otherwise unsuitable for a particular purpose. Sometimes the substance is a manufactured chemical, but just as often it might be microbial contamination" (William 2010). This chapter discusses about the groundwater contamination analysis of the study area, which has been carried out to determine the sources and impact of pollution.

5.2 GROUNDWATER POLLUTION SOURCES

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Variety waste products are disposed of in stream or on the ground. Many types of harmful materials are regularly introduced into subsurface formations and the aquifers. Groundwater is increasingly affected by soluble chemicals and organic materials, due to a way of life in excessive consumption (Zaporozec1981). In general, there are multiple and varied sources of groundwater contamination. Chemical contaminants can leak into groundwater from a variety of sources including waste dumps, sewage land-treatment sites, and injection wells. Microbial contamination occurs, when human and animal wastes containing viruses, bacteria, and parasites come into contact with groundwater and this may lead to large outbreaks of diseases. However, cleaning up these sources of pollution is an extremely an expensive process (Keswick 1984).

A significant change in groundwater quality was noticed in the region of study, where 62% of the residents have confirmed that there is a change in the groundwater quality in the region. This change might have occurred as a result of the following sources:

5.2.1 Natural Sources

Natural sources of pollution contaminate groundwater without human intervention. Even if the groundwater is unaffected by human activities it may still contain some natural impurities. The types and concentrations of natural impurities depend on the nature and type of soil sediment and rock, through which the groundwater moves and affects the quality of the recharge water. Groundwater moving through these layers may pick up a wide range of compounds such as, magnesium, calcium, and chlorides etc. The types and concentrations of natural pollutants determine their effect on groundwater quality. Seawater intrusion associated with over withdrawal from aquifers or natural leaching from naturally occurring deposits are the natural sources of groundwater contamination (Lenntech no date), which lead to increase the rate of dissolved salts in groundwater and thus affects its quality and prevent its use for certain purposes.

Excessive withdrawal of water from underground reservoirs near the coastal strip, especially at places where the aquifers are shallow, without any prior scientific studies have led to the influx of saltwater from the sea that replaces the lost fresh groundwater, and resulted in the salinity of the water exceeded the standards of drinking water (Al-Taira 2004).

In the study area there is a significant increase in salinity levels in some of groundwater wells; where approximately 35.1% of the residents have noticed this change and 54% of them think this increase is due to seawater intrusion. Moreover, some of the chemical analysis has proved the increase of Total Dissolved Solids (TDS), where the concentrations in some wells have exceeded the permissible maximum limits (500-1500 mg/L) (Table 5.1).

5.2.2 Anthropogenic Sources

Groundwater contamination which may due to anthropogenic sources result from various human activities, which produce liquid, solid or gaseous wastes.

Table 5.1 Concentrations of TDS

Well No	TDS	Well No	TDS
1	2183	8	1300
2	1684	9	3100
3	1200	10	920
4	2028	11	4000
5	942	12	750
6	982	13	640
7	8000	14	950

Allowable limit: 500-1500 mg/l.

Source: Field work 2010/2011

a) Sewage Systems

Sewage systems are considered as the biggest source by the volume of waste and pollutants discharged to the land. Urban wastewater systems can be also source of many categories of pollutants, including bacteria, viruses, nitrates from human waste, phosphorus, chloride and organic substances, including organic solvents such as trichloroethylene that are used to clean the systems (David 1996). Injection wells used for domestic wastewater disposal (septic systems, cesspools, drainage wells for storm water runoff, groundwater recharge wells) are very big concern to water quality if they are located near to groundwater sources. Storing or disposing of household chemicals can lead to groundwater contamination, when stored in garages or basements with floor drains, spills and flooding may introduce such pollutants into the groundwater (Lenntech no date**)**. The leakage of wastewater in the region either from septic tanks or through sewage network pipes is considered as a pollution source of groundwater. Discharge of sewage water into soil initiates solute and microbe movement that follows natural groundwater drainage patterns and may pollute groundwater. As the groundwater is mostly used as a source of drinking water, the consumption of such water which contains germs may cause and spread the intestinal disease (James & Neal 2001).

There are two ways for disposal of wastewater in the region:

I. Black Reservoirs (Septic Tanks)

The septic tank system is considered one of the most common sources of groundwater pollution due to their poor locations and designs, as well as construction and maintenance practices. It includes an underground tank, where the sewage is collected and the surface soil absorption system (Figure 5.1), were clarified effluent leaks into the soil and finally reaches the groundwater according to the degree of soil absorption (Larry & Robert 1988).

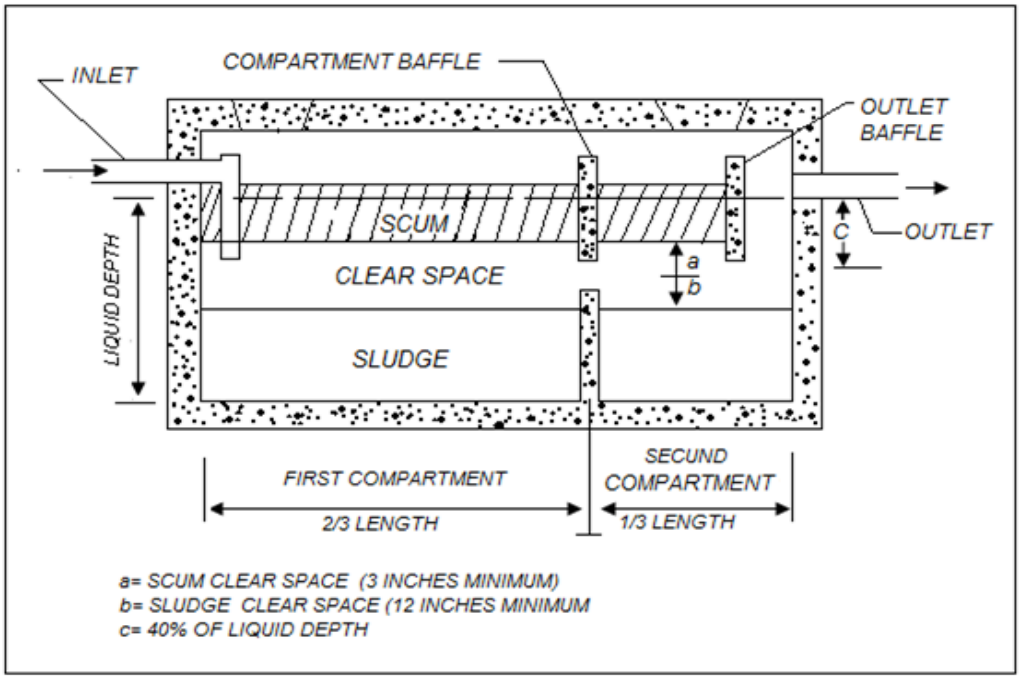

Figure 5.1 Typical Two Compartment Septic Tanks

Source: (Larry & Robert 1988)

Most of the septic tanks in the study area are located in very poor locations, and they are poorly designed and constructed. The septic tank is a hole covered only from the top, and thus the waste water directly move to the soil and then into aquifers. About 72.2% of residents rely on septic reservoirs to dispose their wastewater, and approximately 40.5% of them do not discharge their reservoirs. This method leads to

leakage of pollutants into aquifers especially those reservoirs that are poorly designed and constructed and not properly protected.

II. Sewage Networks

Many Libyan cities are affected by water problems and sanitation network issues, where a lot of streets are experiencing of increased expansion of networks and occurrence of potholes because they are old and dilapidated. This leads to landslides in the soil and leaks the pollutants into aquifers (Al-Mashhad Al-Liby 2010).

The sewage networks in the region were constructed in the sixties, and now they have become unable to accommodate current population density of the region and are dilapidated and spill out sewage (Photograph 5.1).

Photograph 5.1 the Sewage Overflowing in the City of Derna

Source: fieldwork 2010/2011

The sewage overflowing was reckoned based on the poll of residents, where 67% of the respondents confirmed that there was an overflow of sewage. Big ponds of pollutants formed on the surface of the ground, which finally led to soil pollution and even finally leaking into the aquifer. All sewage lift stations have been disrupted and left to neglect and vandalized and finally become garbage landfill (Table 5.2), and thus polluting the beach and leaking into groundwater. Also a sewage treatment

plant which was established in 1980, (Photograph 5.2), the final stages of which was not completed; it was left to neglect and unattended and is now at a dilapidated condition with little use.

Photograph 5.2 Sewage Treatment Plant- Derna Established in 1980 and Stalled Since 1985

Source: fieldwork 2010/2011

Table 5.2 Sewage Lift Stations in the Region

The stations	**1**	**2**	**3**	**4**
Establishment date	1968	1968	1968	1978
Date of start	1970	1970	1970	-
Stopped work date	-	1985	1985	-
Number of pumps	2	4	5	-
Station capacity	13536 m^3/day	5712 m^3/day	360 m^3/day	600 m^3/day
Recipient area of the station	All the city	Aljubaila & Bab Shaiha	Albelad	Alsahil
Current situation	Broken	Broken	Broken	Broken

Source: Bin Imran et al. No date

Preliminary examination of the data revealed that, there is a probability association between the groundwater quality change and the overflowing of sewage. 75.7% of residents have agreed that there is a significant change in the quality of groundwater in areas that have overflowing of wastewater (Table 5.3). Further

analysis using the chi - square method was carried out to identify, whether the association between the groundwater quality change and the overflowing of sewage, is statistically significant. The analysis has revealed a chi-square value of 27.407, which was significant at the 0.05 level (P value = 0.000).

Table 5.3 Perception on sewage overflow and groundwater quality in the City of Derna

Water quality change	**Sewage overflowing**		**Total**
	Overflowing	No overflowing	
Deteriorated	218 (75.7%)	70 (50.4%)	288 (67.4%)
No change	70 (24.3%)	69 (49.6%)	139 (32.6%)
Total	288 (100%)	139 (100%)	427 (100%)

Chi- square = 27.407 Significance = 0.000

Source: Source: fieldwork 2010/2011

b) Solid Waste and Disposal System

In general, solid waste includes different solid materials that are no longer needed by people, which have to be immediately disposed of. Therefore they are considered as one of the environmental pollutants unless they can be disposed in ways that leave no harmful effects to human health and to the safety of the environment or they are recycled (Sharaf 2000).

Transfer and disposal of solid waste in the study area are carried out by a group of trucks of different sizes 2 to 3 trips per day. Where, the daily amounts generated from the Derna city are estimated by 70 tons or about 25550 tons per year and contain of different materials, mostly organic (Environmental Protection Agency 2004). Solid wastes contain many different materials, such as, organic and chemical materials. Table 5.4 shows that solid garbage in Derna contains 70% organic materials, 11% paper, 7% plastic, minerals 5%, various other materials 5% and glass are 2%.

Table 5.4: Components of Domestic Solid Waste in the Study Area

Content of waste	Organic materials	Paper	Plastic	Metallic materials	Glass	Other materials	Total
Proportion	70%	11%	7%	5%	2%	5%	100%

Source: (Environment Protection Agency 2004)

The authorities concerned have not taken into account regarding the effects on human health and the safety of the environment caused by this landfill, where wastes are dumped. The region depends on one of the oldest ways for disposing domestic solid garbage, which is throwing the garbage down in the open dumps and then burn without any processing, (Photograph 5.3).

Photograph 5. 3 Method of Final Disposal of Waste

Source: Source: Field work 2010/2011

What makes the situation worse, these dumps are located very close to residential area but some dumps are on the border of the city's boundary, especially in the east of the city, where the main landfill is located; also there are two dumps at the north western part of the region (Figure 5.2) . Besides that, there is accumulating and stack of waste in the streets and empty places in the region, where about 65% of residents have indicated to that, this happens because of the underperformance of the responsible authorities in cleaning the city and the insufficient number of provided equipments and machinery, which are not enough for the population density and lack

of follow-up to the daily work of cleaning in the city. This waste can decompose and produce many materials that can affect human health and the environment, as well as can leak with rainwater to groundwater, especially most of geological formations are limestone which allows the contaminants to easily leak into aquifers.

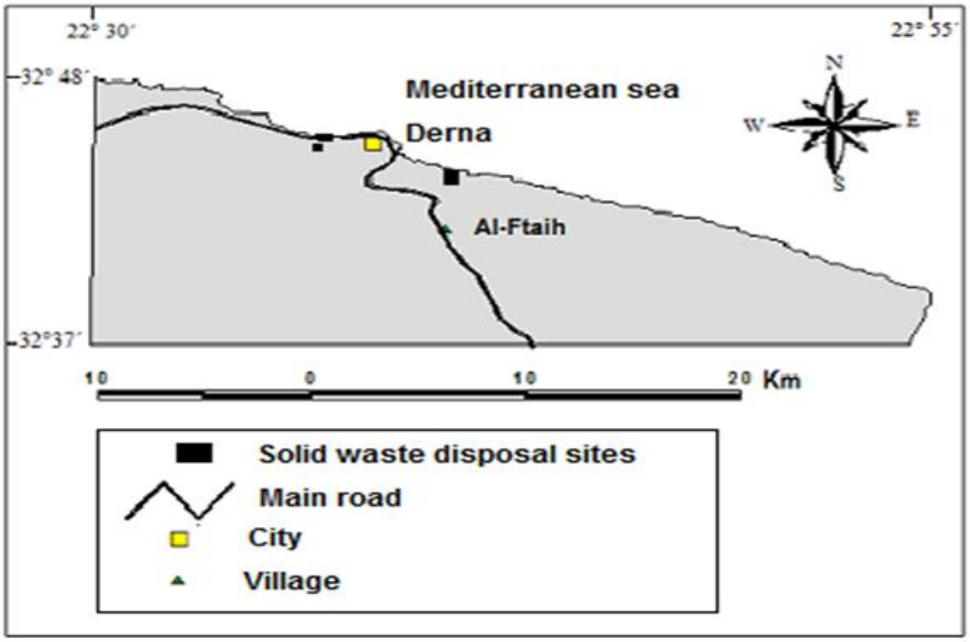

Figure 5.2 Solid Waste Disposal in the Region

Source: Elgali 2006.

Analysis of data showed that there is a possibility of an association between the groundwater quality change and the accumulation solid wastes in many unoccupied places inside the city. It could link the change of groundwater quality and the accumulated solid waste, where more than two thirds of the population have noticed that (Table 5.5). Analysis using the chi-square method was used to determine whether the association between the groundwater quality change and the accumulated solid waste is statistically significant. The analysis yielded a chi-square value of 1.096, and P- value = 0.295.

Table 5.5 Perception on Solid Waste and Groundwater Quality in the City of Derna

Water quality change	Solid waste accumulation		Total
	Accumulate	No accumulate	
Deteriorated	191 (69.2%)	97 (64.2%)	288 (67.4%)
No change	85 (30.8%)	54 (35.8%)	139 (32.6%)
Total	276 (100%)	151 (100%)	427 (100%)

Chi- square = 1.096 Significance = 0.295

Source: field work 2010/2011

c) Excessive Use of Pesticides and Fertilizers in Farmlands

Groundwater pollution caused by excessive use of fertilizers, pesticides and agricultural wastes is an emerging problem in agricultural areas. Therefore, more attention is required to be paid on the possible effect of irrigated agriculture on groundwater quality.

Excessive use of fertilizers and pesticides in farmlands to increase the production of crops, may reach underlying aquifers, especially if these aquifers are shallow and not protected by an overlying layer of low permeability material, such as clay. Fresh water wells that are located nearby farmland are sometimes polluted by these agricultural chemical materials. Chemicals used in agriculture, such as fertilizers, pesticides, and herbicides are sources of nonpoint pollution, because they are spread out across wide areas (Water Encyclopedia no date).

The agriculture consumes a large part of the groundwater in the region, due to lack of rain and frequent reliance on irrigated agriculture. The quantity of water used for agricultural purposes are estimated by 25.6% of the total water uses in the region (Bin Imran et al. No date), and this result in decline of groundwater level and thus increases salinity rate.

The groundwater is exposed to contamination through the leakage of chemicals within agricultural drainage water, as a result of excessive use of fertilizer and pesticides. The chemical fertilizers are resistant, which remain in aquatic environments for long periods. The irrigation-intensive processes speed-up the arrival of these pollutants to groundwater. The impact of pesticides on the groundwater quality is resulted to the quality of the pesticide itself, as well as the quality of irrigation and soil conditions. Nitrates and bacteria in animal and poultry wastes can leak together with rain water percolating to the groundwater (Al-Taira 2004).

I. Pesticides

Most of the pesticides used worldwide pose high risks to human health and the environment. Some of the pesticides cannot be assessed for toxicity due to lack of publicly available data, and to make things worse is that many of them cannot be routinely analyzed by state laboratories, and thus it is not known to what extent they contaminate food and the environment (Oliver & Katja 2008).

Most of the farmlands in the study area are located in the southern and south-eastern part of the region. It is worth noting that pesticides have been widely used in the farms, and these include the herbicides, fungicides, insecticides and rodenticides. The exploratory study showed that 74% of farmers used these pesticides, to get rid of insects and weeds and protect their produce; these pesticides in turn leak and pollute the groundwater directly or indirectly. The direct pollution is caused due to the spreading of pesticides around the wells, use of the pesticides in the irrigation systems or due to poor storage, while the indirect pollution occurred when the pesticides leak down through the soil in places where pesticides are mixed or in the areas of normal use. In both cases, these pollutants eventually reach the groundwater (Al-Taira 2004).

In principle, the data examined showed that there is a possible association between the groundwater quality change and the pesticide usage. 56.5% of farmers stated that, there is a significant change in the quality of groundwater in the agricultural areas, and most of them have used the pesticides in their farms (Table 5.6). On the other hand, the Chi - square analysis was carried out, to identify whether

the association between the groundwater quality change and the usage of pesticides is statistically significant. The analysis has revealed a Chi-square value of 4.960, which was significant at the 0.05 level (P value = 0.026).

Table 5.6 Perception on Pesticide Usage and Groundwater Quality in Al-Ftaih town

Water quality change	**Pesticide usage**		**Total**
	Use	**Not use**	
Deteriorated	11 (73.3%)	2 (25%)	13 (56.5%)
No change	4 (26.7%)	6 (75%)	10 (43.5%)
Total	15 (100%)	8 (100%)	23 (100%)

Chi- square = 4.960 Significance = 0.026.

Source: Field work 2010/2011

II. Fertilizers

Apart from the pesticides, some of the chemical compounds originating from fertilizers were reported to be a primary source of groundwater contamination. Fertilizers are nutrients needed by crops, and considered as improvers when added to the soil to improve its chemical and physical properties. These fertilizers including nitrogen, phosphorus and potassium compounds. The soil absorbs phosphorus and potassium easily, but the dissolved nitrogen compounds such as ammonia and nitrite are only partly absorbed by the soil and plants, while the remaining part moves downward with water to the aquifers, which leads to water pollution and reduces its value and suitability for human use (Al-Taira 2004).

A study conducted by the Arab Organization for Agricultural Development, warned on the excessive use of chemical fertilizers, which has increased the availability of elements that are harmful to humans and animals in some Arab countries. The study found that the use of fertilizers in the Arab world is increasing steadily, with the admission of the extensive extent of the accumulation of these fertilizers in soil, surface water, and groundwater. It is a serious environmental

problem, especially in arid and semi arid countries like Libya, where the groundwater is the main source of crops irrigation (Saline Water Conversion Corporation 2010).

Most of the farmers in the region are using many types of fertilizers, in order to improve the fertility of soil so as to increase production. There are, about 65% of them who are using fertilizers, and this in turn affects the groundwater quality in the region.

The analysis of the data has indicated that there is a possibility of a relationship between the groundwater quality change and the fertilizer usage. 80% of farmers who use the fertilizers have noticed that there is a significant change in the quality of groundwater in the agricultural areas (Table 5.7). The Chi-square method was carried out to identify, whether the relationship between the groundwater quality change and the usage of fertilizer is statistically significant. The analysis has yielded a Chi-square value of 6.626, which was significant at the 0.05 level (P value = 0.010).

Table 5.7 Perception on Agricultural Fertilizers Usage and Water Quality in Al-Ftaih town

Water quality change	**Fertilizer usage**		**Total**
	Use	**Not use**	
Deteriorated	12(80%)	2 (25%)	14 (60.9%)
No change	3(20%)	6 (75%)	9 (39.1%)
Total	15 (100%)	8 (100%)	23 (100%)

Chi- square = 6.626 Significance = 0.010

Source: Source: Field work 2010/2011

Al-Taira (2004) has reached similar result about the main factors of groundwater contamination in Benghazi, where liquid waste was at the forefront of these factors, as a result of poor infrastructure in the region.

5.3 QUALITY OF GROUNDWATER IN THE STUDY AREA

The groundwater quality is a term, which indicates its physical, chemical, and biological characteristics as they relate to the intended purpose of the water. In spite of

harmful materials that are sometimes introduced by natural processes into aquifers, human activities are considered as the main factors that threat the groundwater quality. Sustainable groundwater management must be based on the prevention of the excessive exploitation and prevention of contamination of groundwater resources (UNESCO 2002).

The nature of the geological structure of the soil determines the physical and chemical composition of the groundwater. Water is constantly in contact with the ground, whether it stagnates or circulates, so equilibrium develops between the composition of the soil and that of the water, in other words; water that circulates in a sandy or granitic substratum is acidic and has few minerals. Water that circulates in limestone contains bicarbonate alkalinity (Lenntech no date). (Table 5.8) compares the characteristics of surface water and groundwater based on the major analysis parameters.

5.3.1 Microbiological Properties of Groundwater

The colony bacteria (E. coli) naturally live in the colon and small intestine in the human body by limited rates. It is important to perform some vital functions such as oxidation of some vital materials and iron absorption. If their number increases, they will cause risk to human life; which leads to the inflammation of the bowel wall and blood poisoning in worst cases, apart from causing diarrhea, fever, acidity in the blood and affect the kidney as well. water-borne algae and bacteria can survive in areas contaminated by sewage and other organic matter, so they are usually used as indicators for pollution (Al-Taira 2004). Coliform bacteria are usually used as an indicator of bacterial pathogen contamination in water. The presence of such bacteria means the probable presence of microorganisms that may cause harmful effects in humans (James & Neal 2001).

Table 5.8 Comparison Between the Characteristics of Surface Water and Groundwater

Characteristic	**Surface Water**	**Groundwater**
Temperature	Varies with season	Relatively constants
Turbidity, SS	Level variable, sometimes high	Low or nil (except in karst soil)
Colour	Due mainly to SS (clays, algae) except in very soft or acidic waters (humic acids)	Due above all to dissolved solids
Mineral content	Varies with soil, rainfall, effluents, etc.	Largely constant, generally appreciably higher than in surface water from the same area
Divalent Fe and Mn in solution	Usually none, except at the bottom of lakes and ponds in the process of eutrophication	Usually present
Aggressive CO_2	Usually none	Often present
Dissolved O_2	Often near saturation level, absent in very polluted water	Usually none
H_2S	Usually none	Often present
NH_4	Found only in polluted water	Often found
Nitrates	Level generally low	Level sometimes high
Silica	Usually moderate proportions	Level often high
Mineral and organic micro-pollutants	Can be present but liable to disappear rapidly once the source is removed	Usually none but any accidental pollution lasts a very long time
Living organisms	Bacteria, viruses, plankton	Iron bacteria frequently found
Chlorinated solvents	Rarely present	Often present
Eutrophic nature	Often. Increased by high temperatures	None

Source: Lenntech 1988.

E. coli is a bacterium used by Tegel as a microbial indicator, as it indicates diseases from warm blooded animals and humans; and thus, it is an indicator of sewage pollution (Al-Taira 2004). The international standards for drinking water specify that, the coliform counts in drinking water should not be more than 10 counts per 100 ml of sample (Daniel no date).

As stated in the standards for water bacteria, the presence of coliform bacteria by 0-10 in each 100 cm^3 of water, means the water is suitable for drinking, and an increase of bacteria ratios from 11-50 in each 100 cm^3 makes the water not suitable for drinking, while if they increase from 51 and above in each 100 cm^3 of water, indicates that the water is not suitable for all human uses (Al-Taira 2004).

In the study area, bacterial pollution is the largest concern for groundwater. This may be due to the poor performance and lack of interest in sewage management, where most of the sewage networks are dilapidated, as well as relying on septic tanks in the disposal of sewage, especially in random residential areas and developing neighbourhoods.

Thirty-one groundwater supplies were examined under bacterial analysis to determine the microbiological properties of water and suitability of water for drinking and other human purposes. (Tables 5.9 & 5.10) show that most of water samples collected are not suitable as drinking water because there was a bacterial growth and this controversy to the Libyan standard specifications for drinking water as well as poses threat to human health. In general, there was an increase in the coliform bacteria ratios, the highest recorded coliform bacteria count was 100 in each 100 cm^3 of water, and thus it is not suitable for drinking and other human uses. Most of the population depends on desalinated water.

Table 5.9 Bacterial Analysis of Springs

No	**Colony bacteria in 100 cm^3**		**Result**
	Mix growth	**E. coli**	
1	Over count	22	Not suitable for drinking
2	Over count	6	Not suitable for drinking

Source: Field work 2010/2011

Table 5.10 Bacterial Analysis of Wells

Well No	Colony bacteria in 100 cm3		Result
	Mix growth	E. coli	
1	Over count	0	Not suitable for drinking
2	18	100	Not suitable for drinking
3	Over count	23	Not suitable for drinking
4	Over count	7	Not suitable for drinking
5	9	0	Suitable
6	7	0	Suitable
7	13	0	Not suitable for drinking
8	23	0	Not suitable for drinking
9	9	0	Suitable
10	2	0	Suitable
11	Over count	0	Not suitable for drinking
12	Over count	100	Not suitable for drinking
13	Over count	3	Not suitable for drinking
14	Over count	5	Not suitable for drinking
15	Over count	9	Not suitable for drinking
16	Over count	2	Not suitable for drinking
17	45	7	Not suitable for drinking
18	60	23	Not suitable for drinking
19	Over count	0	Not suitable for drinking
20	Over count	9	Not suitable for drinking
21	Over count	11	Not suitable for drinking
22	83	29	Suitable
23	Over count	88	Not suitable for drinking
24	Over count	0	Not suitable for drinking
25	8	13	Not suitable for drinking
26	13	19	Not suitable for drinking
27	Over count	0	Not suitable for drinking
28	Over count	33	Not suitable for drinking
29	Over count	12	Not suitable for drinking

Source: Field work 2010/2011

5.3.2 Chemical Properties of Groundwater

The chemical properties of water are important factors to be considered, before it is used for domestic, agricultural or industrial purposes (Ashraf et al. 2011). Sixteen

groundwater supplies were examined to determine the chemical properties of the water. Chemical analysis showed to some variations in the chemical properties of the water. (Tables 5.11 and 5.12) show the following evaluation results:

a. The groundwater in the study area is neutral to slightly alkaline as its pH varies from 6.8 to 8.1.

b. The maximum value of EC was 12050 μ S/cm, and the minimum was 780 μ S/cm in Spring of Abu-Mansour, with a mean of 2630.417 μS/cm, this is of course given to the increase of salts.

c. The TDS values in some wells have exceeded the permissible maximum limits with an average of 1,889.923 mg/L and the maximum was 8000 mg/L. The high amount of TDS in groundwater may be due to seawater intrusion and low water level resulting from an increase of withdrawal with lack of rain particularly in the summer season.

d. Five wells have high concentrations of T.H and exceeded the allowable maximum limit, where the highest value was 1700 mg/L.

e. As can be seen from the (Table 5.11) the Ca++ concentrations in the water samples are within allowed limits except one which was 280 mg/L.

f. Fe, NH_4 and NO_2 concentrations are found to be below permissible limits for drinking water in some samples.

g. One sample has a very high concentration of C1, which was 1140 mg/L, and the C1 has exceeded the permissible limit in about 28% of samples. PO_4 was existent in three wells.

h. The springs are almost clean of high chemical concentrations which exceed the standard of drinking water.

Table 5.11 Chemical Parameters of Groundwater Quality in Wells

Parameters	**pH**	**EC**	**TDS**	**T.H**	**Ca++**	**Mg++**	**Fe**	**NH_4**	**C1**	**NO_2**	**PO_4**
Permissible limit	7-8.5	-	1000	500	200	150	0.3	0.5	250	1	0.1
1	7.0	1638	982	400	64	58	0	0	140	0	0
2	7.7	1900	950	380	96	34	0.1	0.2	180	0.2	1
3	7.3	790	640	320	64	64	0	0	160	0	0
4	-	12050	8000	1700	280	243	0	0	1140	0	-
5	6.8	3380	2028	900	186	116	0	0	360	0	0
6	7.0	1570	942	380	88	38	0	0	180	0	0
7	7.4	2950	2183	750	160	92	0	0	260	0	0
8	7.0	1777	1200	560	136	53	0	0	160	0	0
9	7.8	2340	1684	640	112	87	0	0	240	0	0. 5
10	-	-	4000	-	-	-	0	0	-	0	1
11	-	1300	750	340	56	32	0	0	80	0	0
12	-	1933	1300	360	88	34	0.1	0	180	0	-
13	-	4650	3100	300	104	10	0.2	0	300	0	0
14	-	1518	920	550	88	31	0.1	0	120	0	-

All parameters expressed in mg/L except pH and EC, where EC in μS/cm and pH has no units.

Source: Field work 2010/2011

Table 5.12: Chemical Parameters of Water Quality in the Springs

Parameters	**PH**	**EC**	**TDS**	**T.H**
Permissible limit	7-8.5	-	1000	500
Spring of Al-Bilad	7.0	1090	700	350
Spring of Abu-Mansour	8.1	780	510	240

All parameters expressed in mg/L except pH and EC, where EC in μS/cm and pH has no units.

Source: Field work 2010/2011

5.4 COMPARING OF MEANS OF GROUNDWATER PARAMETERS CONCENTRATIONS AMONG THE REGION'S SECTIONS

For this serious environmental problem the one way analysis of variance (ANOVA) was applied to examine the mean differences in E. coli count in and its spread extent among the sections of the region, as well as to examine the mean differences in most important chemical parameter concentrations.

One of the objectives of the study is to identify the spatial distribution of groundwater contamination in the study area. Accordingly, the following are the form of statistical hypotheses in the case of one-way ANOVA:

Null Hypothesis (H0) = the concentrations of groundwater pollutants are not equal between the region's sections, or at least three or four sections are not equal.

Alternative Hypothesis (H1) = the concentrations of groundwater pollutants are equal between the region's sections, or ($\mu1 = \mu2 = \mu3 = \mu4 = \mu5 = \mu6 = \mu7$).

E. coli: Preliminary analysis of the data has revealed that an average of E.coli count in all sections of the region was 16.8065 in each 100 cm^3, but the average for the eight sections seemed to be different and most of them are above than the permissible limit on Libyan standards. The groundwater wells in Al-Belad had the highest average of E. coli count (50) and the Al-Sahil's wells the lowest (6.7), (Table 5.13) and (Figure 5.3). The ANOVA analysis has indicated that (P value = 0.814), it

exceeds the significant level (5%), and thus accept the null hypothesis. Therefore it can be concluded that the E. coli count are not equal between the sections of the region i.e. three or four sections at least are not equal due to varies reasons causing the problem such as, varied of environmental and infrastructure services among the region's sections, where sewage overflow in some areas due poor of sewage networks while there is surplus of sewage tanks in other areas.

Table 5.13 Descriptive Statistics of E. coli Counts 100cm^3 on Groundwater Among the Region's Sections

The region's sections	Minimum	Maximum	Mean (count)
Al-Maghar	0.00	100.00	12.5000
Abu-Msafir	7.00	23.00	15.0000
Al-Belad	0.00	100.00	50.0000
Al-Jubaila	2.00	23.00	9.2500
Abu-Mansour	0.00	88.00	23.6667
Al-Sahil	0.00	13.00	6.6667
Al-Ftaih	0.00	33.00	16.0000
The Springs	6.00	22.00	14.0000

F = 0.515 Significance = 0.814.

Source: Field work 2010/2011

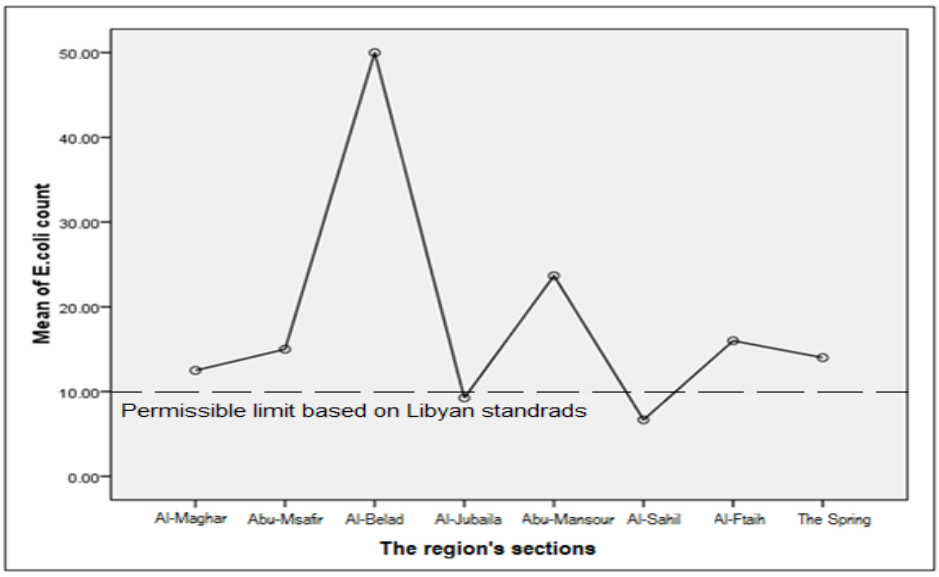

Figure 5.3 Graph Shows the E. coli counts (in 100cm3) Among the Region's Sections

Source: Field work 2010/2011

As discussed previously, one of the objectives of the study is to identify the spatial distribution of groundwater contaminants (parameters) in the study area. Therefore, one way analysis of variance (ANOVA) was used to examine the mean variation of concentration of the most important chemical parameters in the groundwater such as; TDS, TH, EC, Ca, Mg and Cl in mg/L.

TDS: the initial analysis of the TDS data revealed that the overall means of TDS concentration in all sections of the region was 1976.3571 mg/L, but the sectional averages of the region seemed to be different and most of them are above than the permissible limit on Libyan standards. The highest average value of TDS concentration was 4320 mg/L and it is found in groundwater wells of Abu-Msafir area, and this average is four times greater than the allowed maximum limit based on Libyan standards for drinking water, which is 1000 mg/L. Whereas, the lowest concentration was 605 mg/L in the spring area (Table 5.14) and (Figure 5.4).

Table 5.14 Descriptive Statistics of TDS (mg/L) on Groundwater Among the Region's Sections

The region's sections	**Minimum**	**Maximum**	**Mean (mg/L)**
Al-Maghar	950.00	982.00	966.00
Abu-Msafir	640.00	8000.00	4320.00
Al-Belad & Al-Jubaila	942.00	2028.00	1485.00
Abu-Mansour	1200.00	2183.00	1691.50
Al-Sahil	1684.00	4000.00	2842.00
Al-Ftaih	750.00	3100.00	1925.00
The Springs	510.00	700.00	605.00

F = 0.657 Significance = 0 .687

Source: Field work 2010/2011

The ANOVA analysis showed the significant result with F-ratio of 0.657, which was not significant at the 0.10 level (P.value = 0 .687), it is more than the level of significance, and thus the null hypothesis is accepted. It can be concluded that there is a significant difference between the TDS concentrations in the sections of the region.

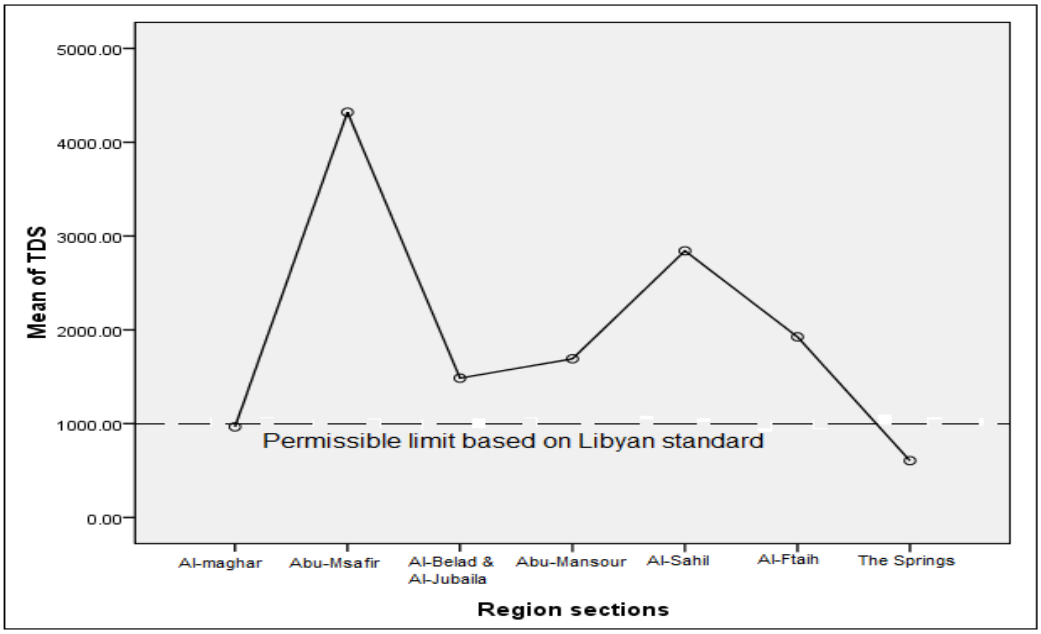

Figure 5.4: Graph Shows the Means of TDS (mg/L) Among the Region's Sections

Source: Field work 2010/2011

Analysis of data using one-way ANOVA technique showed that the TDS concentrations differed among the region's sections, but has not indicated which section differed from the other sections in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.15).

TH analysis of TH data showed that the overall average of TH concentrations of the region was 536.4386 mg/L, but the sectional averages for the all sections vary. It was found that the TH concentrations in groundwater in three sections were only higher than the permissible limit on the Libyan standards.

The highest average of TH concentration was 1010 mg/L and found in Abu-Msafir area, and this value is double that of the maximum allowable of the Libyan standard for drinking water which is 500 mg/L. Meanwhile, the lowest concentration was 295 mg/L in the spring area (Table 5.16) and (Figure 5.5).

Table 5.15 Differences of TDS (mg/L) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	3354	.170
Al-Maghar and Al-Belad	519	.820
Al-Maghar and Abu-Mansour	725	.750
Al-Maghar and Al-Sahil	1876	.420
Al-Maghar and Al-Ftaih	959	.675
Al-Belad and Abu-Msafir	2835	.237
Al-Belad and Abu-Mansour	206.5	.928
Al-Belad and Al-Sahil	1357	.555
Al-Belad and Al-Ftaih	440	.847
Abu-Mansour and Abu-Msafir	2628.5	.269
Abu-Mansour and Al-Sahil	1150.5	.616
Abu-Mansour and Al-Ftaih	233.5	.918
Al-Sahil and Abu-Msafir	1478	.522
Al-Ftaih and Abu-Msafir	2395	.311
Al-Ftaih and Al-Sahil	917	.688
Springs and Al-Maghar	361	.874
Springs and Abu-Msafir	3715	.134
Springs and Al-Belad	880	.700
Springs and Abu-Mansour	1086.5	.635
Springs and Al-Sahil	2237	.341
Springs and Al-Ftaih	1320	.566

Source: Field work 2010/2011

Table 5.16 Descriptive Statistics of TH (Mg/L) on Groundwater Among the Region's Sections

The region's sections	Minimum	Maximum	Mean (mg/L)
Al-Maghar	380.00	400.00	390.00
Abu-Msafir	320.00	1700.00	1010.00
Al-Belad & Al-Jubaila	380.00	900.00	640.00
Abu-Mansour	560.00	750.00	655.00
Al-Sahil	.00	640.00	320.00
Al-Ftaih	340.00	550.00	445.00
The Springs	240.00	350.00	295.00

F = 0.669 Significance = 0.680

Source: Field work 2010/2011

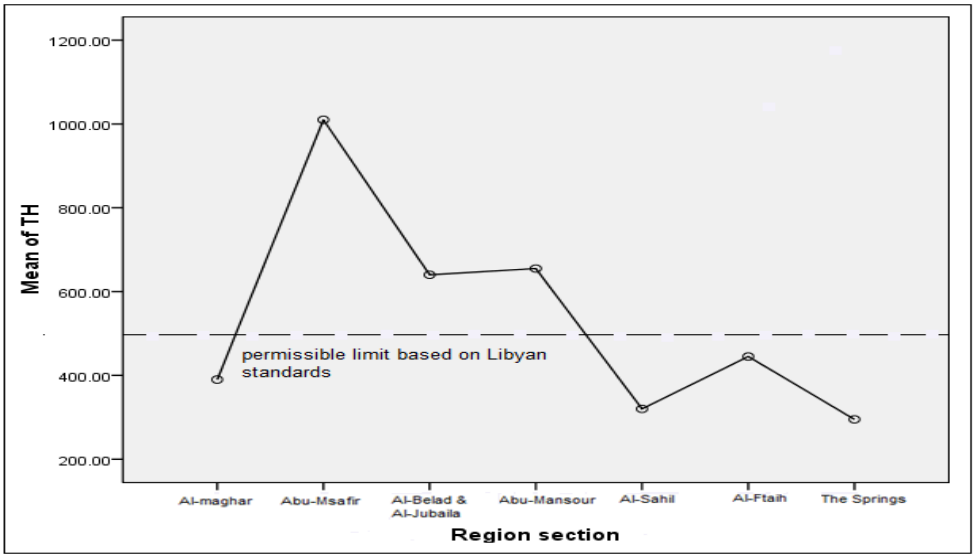

Figure 5.5 Graph Shows the Means of TH (mg/L) Among the Region's Sections

Source: Field work 2010/2011

The analysis of one-way ANOVA shows a significant result with F-ratio of 0.669, which was not significant at the 0.10 level (P.value = 0.680), and it can be concluded that, there is a difference between the TH concentrations in sections of the region.

Analysis of data using one-way ANOVA technique showed that the TH concentrations differed among the region's sections, but did not reveal which section differed from the others in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.17).

EC: The mean value of EC concentration in all sections of the region was 2586.79 µS/cm, however, the averages for the various sections of the region did not seem to match, because there are minor differences. The highest average of EC concentration was 6420 µS/cm and found in Al-Abu-Msafir in the central part of Derna city. Whereas, the lowest concentration was 935 µS/cm, in the spring area (Table 5.18) and (Figure 5.6). The one-way ANOVA analysis revealed that F-ratio = 0.669, which was not significant at the 0.10 level (P.value = 0.680). Therefore, the null hypothesis is accepted, and it can be concluded that there are differences between the EC concentrations in the sections of the region.

Table 5.17 Differences of TH (mg/ L) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	620	.199
Al-Maghar and Al-Belad	250	.585
Al-Maghar and Abu-Mansour	265	.564
Al-Maghar and Al-Ftaih	55	.903
Al-Belad and Abu-Msafir	370	.425
Al-Belad and Abu-Mansour	15	.974
Abu-Mansour and Abu-Msafir	355	.444
Al-Sahil and Al-Maghar	70	.877
Al-Sahil and Abu-Msafir	690	.159
Al-Sahil and Al-Belad	320	.488
Al-Sahil and Abu-Mansour	335	.469
Al-Sahil and Al-Ftaih	125	.783
Al-Ftaih and Abu-Msafir	565	.237
Al-Ftaih and Al-Belad	195	.669
Al-Ftaih and Abu-Mansour	210	.646
Springs and Al-Maghar	95	.834
Springs and Abu-Msafir	715	.146
Springs and Al-Belad	345	.456
Springs and Abu-Mansour	360	.438
Springs and Al-Sahil	25	.956
Springs and Al-Ftaih	150	.742

Source: Field work 2010/2011

Table 5.18 Descriptive Statistics of EC (µS/cm) on Groundwater Among the Region's Sections

The region's sections	Minimum	Maximum	Mean (µS/cm)
Al-Maghar	1638.00	1900.00	1769.00
Abu-Msafir	790.00	12050.00	6420.00
Al-Belad & Al-Jubaila	1570.00	3380.00	2475.00
Abu-Mansour	1777.00	2950.00	2363.50
Al-Sahil	.00	2340.00	1170.00
Al-Ftaih	1300.00	4650.00	2975.00
The Springs	780.00	1090.00	935.00

F = .639 Significance = .699

Source: Field work 2010/2011

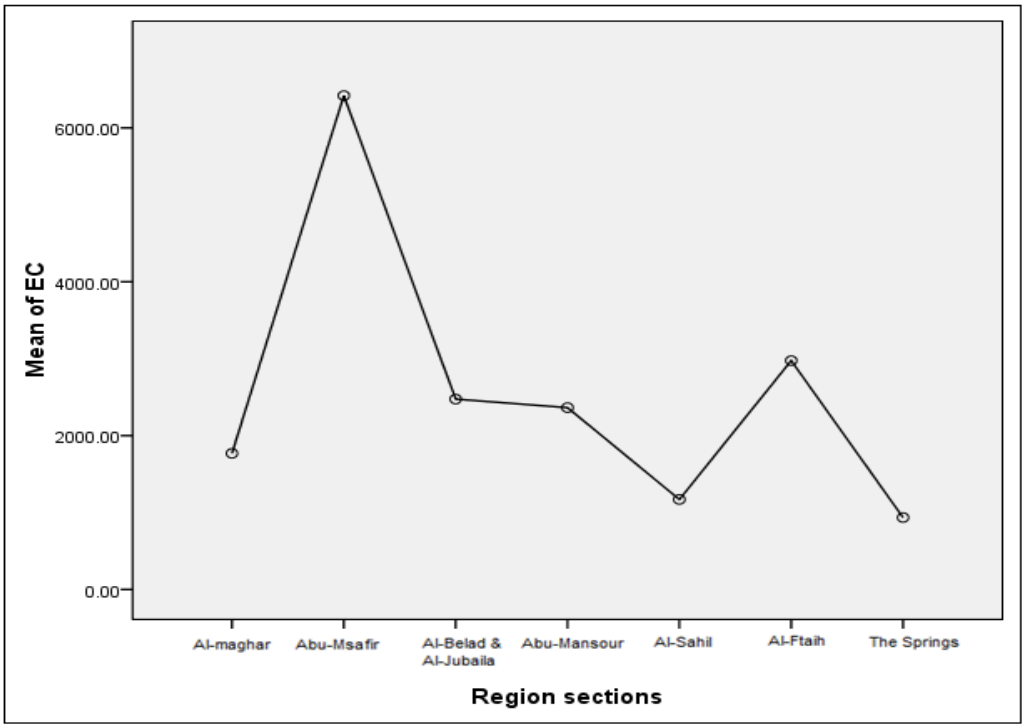

Figure 5.6 Graph Shows The Means of EC (µS/cm) Among the Region's Sections

Source: Field work 2010/2011

Analysis of data using one-way ANOVA technique has shown that the EC concentrations differed among the region's sections, but did not reveal which section differed from the other sections in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.19).

Ca++: the preliminary analysis of the Ca data, has revealed that, the mean of Ca concentration in all sections of the region was 112 mg/L and it is less than the permissible limit (200 mg/L), but the averages for the all sections of the region vary and most of them are less than the allowed maximum limit based on Libyan standards.

The highest average of Ca concentration was 172 mg/l in the Abu - Msafir area in the north-western part of the region. Whereas, the lowest concentration was 56 mg/L in Al-Sahil in the north-eastern part of the region (Table 5.20) and (Figure 5.7).

Table 5.19 Differences of EC (µS/cm) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	4651	.196
Al-Maghar and Al-Belad	706	.834
Al-Maghar and Abu-Mansour	594	.860
Al-Maghar and Al-Ftaih	1206	.722
Al-Belad and Abu-Msafir	3945	.265
Al-Belad and Al-Ftaih	500	.882
Abu-Mansour and Abu-Msafir	4056	.253
Abu-Mansour and Al-Belad	111	.974
Abu-Mansour and Al-Ftaih	611	.856
Al-Sahil and Al-Maghar	599	.859
Al-Sahil and Abu-Msafir	5250	.151
Al-Sahil and Al-Belad	1305	.700
Al-Sahil and Abu-Mansour	1193.5	.725
Al-Sahil and Al-Ftaih	1805	.596
Al-Ftaih and Abu-Msafir	3445	.325
Springs and Al-Maghar	834	.805
Springs and Abu-Msafir	5485	.136
Springs and Al-Belad	1540	.650
Springs and Abu-Mansour	1428	.674
Springs and Al-Sahil	235	.944
Springs and Al-Ftaih	2040	.551

Source: field work 2010/2011

Table 5.20: Descriptive Statistics of Ca++ (mg/L) on Groundwater Among The Region's Sections

The region's sections	Minimum	Maximum	Mean (mg/L)
Al-Maghar	64.00	96.00	80.0000
Abu-Msafir	64.00	280.00	172.0000
Al-Belad & Al-Jubaila	88.00	186.00	137.0000
Abu-Mansour	136.00	160.00	148.0000
Al-Sahil	.00	112.00	56.0000
Al-Ftaih	56.00	104.00	80.0000

F =.707 Significance = .640

Source: Field work 2010/2011

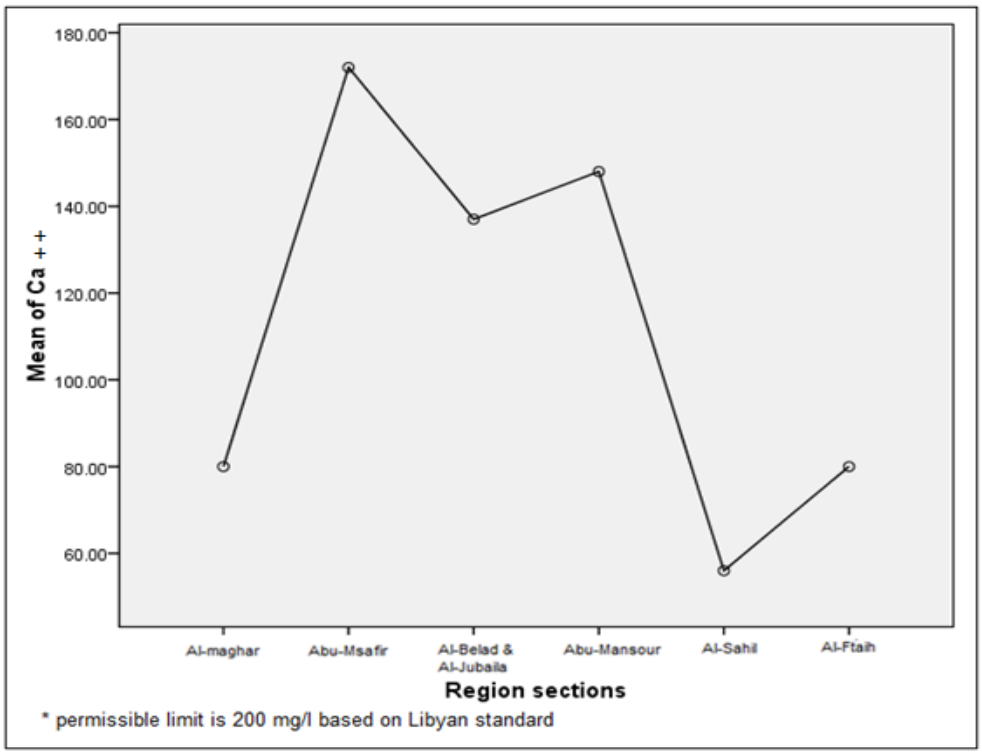

Figure 5.7 Graph Shows the Mean of Ca++ (mg/L) Among The Region's Sections

Source: Field work 2010/2011

The one- way ANOVA analysis showed that the F-ratio = 0.657 at (P.value = 0 .687), it is more than the significant level of 0.10. Therefore, it can be concluded that there are significant differences between the Ca concentrations in the sections of the region.

The one-way ANOVA technique analysis has yielded that, the Ca concentrations differed among the various sections of the region, but has not revealed which section differed from the other sections in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.21).

Mg++: the initial analysis of the Mg data revealed that the mean of Mg concentration in all parts of the study area was 68.92 mg/L and it is less than the permissible limit (150 mg/L). However, when comparing the averages in the region's sections it was found that, most of averages seemed to be below the maximum level except Abu-Msafir area in the north-western part of the region which was 153.5 mg/L, and it is the highest value and above than the permissible limit based on Libyan

standards, The lowest concentration was 21 mg/L in Al-Ftaih area in the southeastern part of the region (Table 5.22) and (Figure 5.8).

Table 5.21 Differences of Ca++ (mg/L) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	92	.282
Al-Maghar and Al-Belad	57	.492
Al-Maghar and Abu-Mansour	68	.416
Al-Belad and Abu-Msafir	35	.669
Al-Belad and Abu-Mansour	11	.892
Abu-Mansour and Abu-Msafir	24	.768
Al-Sahil and Al-Maghar	24	.768
Al-Sahil and Abu-Msafir	116	.187
Al-Sahil and Al-Belad	81	.338
Al-Sahil and Abu-Mansour	92	.282
Al-Sahil and Al-Ftaih	24	.768
Al-Ftaih and Abu-Msafir	92	.282
Al-Ftaih and Al-Belad	57	.492
Al-Ftaih and Abu-Mansour	68	.416

Source: Field work 2010/2011

Table 5.22 Descriptive Statistics of Mg++ (mg/L) on Groundwater Among the Region's Sections

The region's sections	Minimum	Maximum	Mean (mg/L)
Al-Maghar	34.00	58.00	46.0000
Abu-Msafir	64.00	243.00	153.5000
Al-Belad & Al-Jubaila	38.00	116.00	77.0000
Abu-Mansour	53.00	92.00	72.5000
Al-Sahil	.00	87.00	43.5000
Al-Ftaih	10.00	32.00	21.0000

F= 1.064 *Significance = .462*

Source: Field work 2010/2011

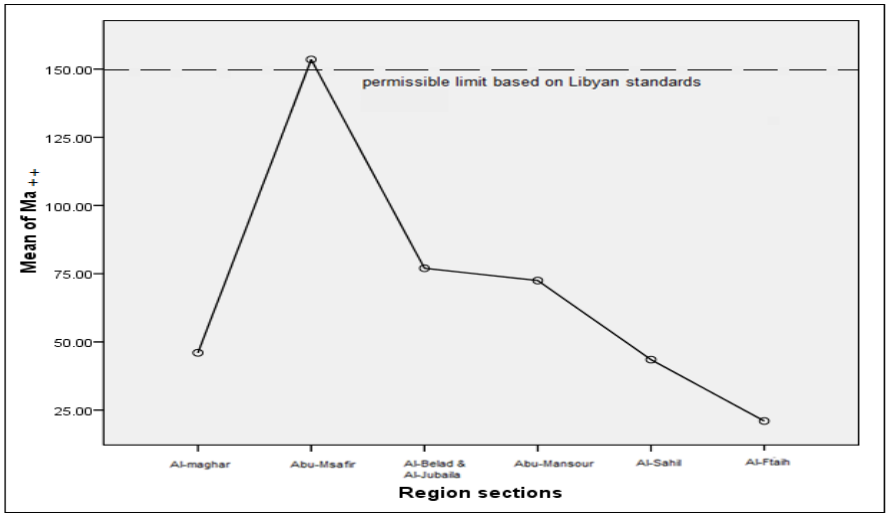

Figure 5.8: Graph Shows the Mean of Mg++ (mg/L) Among The Region's Sections

Source: Field work 2010/2011

Analysis of data using one-way ANOVA technique has yielded that the Mg concentrations slightly differed among the sections averages, but did not reveal which section differed from the other sections in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.23).

Table 5.23 Differences of Mg++ (mg/L) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	107.5	.141
Al-Maghar and Al-Belad	31	.642
Al-Maghar and Abu-Mansour	26.5	.691
Al-Belad and Abu-Msafir	76.5	.273
Abu-Mansour and Abu-Msafir	81	.249
Abu-Mansour and Al-Belad	4.5	.946
Al-Sahil and Al-Maghar	2.5	.970
Al-Sahil and Abu-Msafir	110	.134
Al-Sahil and Al-Belad	33.5	.616
Al-Sahil and Abu-Mansour	29	.664
Al-Ftaih and Al-Maghar	25	.707
Al-Ftaih and Abu-Msafir	132.5	.082
Al-Ftaih and Al-Belad	56	.411
Al-Ftaih and Abu-Mansour	51.5	.448
Al-Ftaih and Al-Sahil	22.5	.735

Source: Field work 2010/2011

Cl: the initial analysis of the Cl data showed that the mean of chlorides concentration in all parts of the region was 266.67mg/L and it is slightly higher than the permissible limit (250 mg/L). However, the averages for all the sections of the region showed only two of them are above the maximum limit of Libyan standards. The highest average concentration of Cl was found in Abu-Msafir area in the north-western part of the region, which was 650 mg/L, and the average lowest concentration was 120 mg/l in Al-Sahil in the north-eastern part of the region (Table 5.24(and (Figure 5.9). The analysis of one-way ANOVA has shown that the F-ratio = .817 at (P.value =.579). Therefore, it can be concluded that the Cl concentrations in all sections of the region are not equal.

Table 5.24 Descriptive Statistics of Cl (mg/L) on Groundwater Among the Region's Sections

The region's sections	Minimum	Maximum	Mean (mg/L)
Al-Maghar	140.00	180.00	160.00
Abu-Msafir	160.00	1140.00	650.00
Al-Belad & Al-Jubaila	180.00	360.00	270.00
Abu-Mansour	160.00	260.00	210.00
Al-Sahil	.00	240.00	120.00
Al-Ftaih	80.00	300.00	190.00

F= .817 Significance = .579

Source: Field work 2010/2011

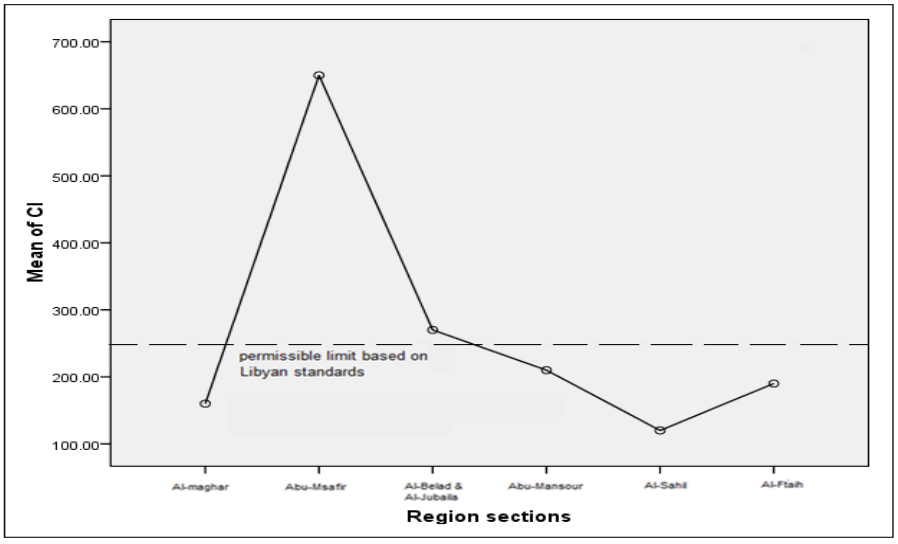

Figure 5.9 Graph Shows the Mean of Cl (mg/L) Among the Region's Sections

Source: Field work 2010/2011

The analysis of data using one-way ANOVA technique has yielded that the Cl concentrations slightly differed among the region's sections, but did not reveal which section differed from the other sections in the region. To detect this, the Post Hoc test was conducted and the result is presented in (Table 5.25).

Table 5.25 Differences of Cl (mg/L) Among the Region's Sections Using Post Hoc Test

Region's Sections	Mean Difference	Significance Level
Al-Maghar and Abu-Msafir	490	.158
Al-Maghar and Al-Belad	110	.730
Al-Maghar and Abu-Mansour	50	.875
Al-Maghar and Al-Ftaih	30	.925
Al-Belad and Abu-Msafir	380	.258
Abu-Mansour and Abu-Msafir	440	.198
Abu-Mansour and Al-Belad	60	.850
Al-Sahil and Al-Maghar	40	.900
Al-Sahil and Abu-Msafir	530	.132
Al-Sahil and Al-Belad	150	.639
Al-Sahil and Abu-Mansour	90	.777
Al-Sahil and Al-Ftaih	70	.826
Al-Ftaih and Abu-Msafir	460	.181
Al-Ftaih and Al-Belad	80	.801
Al-Ftaih and Abu-Mansour	20	.950

Source: Field work 2010/2011

5.6 CONCLUSION

This chapter discussed the main sources of groundwater pollution in the study area. It focused on the key factors behind this serious environmental problem in the study area. Most of these factors were due to human activities such as solid waste accumulation, overflowing of sewage and the excessive use of pesticides and fertilizers. On the other hand, this chapter had also discussed the microbiological and chemical characteristics of groundwater in the region. Furthermore, one-way analysis

of variance (ANOVA) was applied to determine some differences between the concentrations of each parameter among the parts of the region of study. These differences may be due to the variations in the factors that caused the problem, whether they were natural or man-made.

CHPTER VI

SPATIAL ANALYSIS OF GROUNDWATER QUALITY

6.1 INTRODUCTION

This chapter attempts to achieve two of the study objectives. The focus was on the spatial analysis of groundwater quality, where the spatial distribution of chemical and bacterial parameters of groundwater quality has been discussed. Geographic Information Systems (GIS) has been employed to produce distribution maps for the concentrations of groundwater parameters. Furthermore this study also provided information on the characteristics of groundwater quality and have discussed its suitability for human consumption in the study region, based on calculated Water Quality Index (WQI) values. The Multivariate Linear Regression (MLR) has been applied to investigate the relationship between the water-quality factors and their impact on the water quality index.

6.2 SPATIAL DISTRIBUTION OF GROUNDWATER POLLUTION

Groundwater is an important resource for exploitation in arid and semi -arid regions (Taghizadeh et al. 2008). It is threatened by pollution, due to the prolonged aridity and human activities (Sharaf & Subyani 2011). Therefore, in order to protect the quality of groundwater, spatial and temporal data distribution are important. Knowledge on potable groundwater recovery is significant in quality-deteriorated regions, due to the scarcity of surface water and unfavorable climatic conditions (Taghizadeh et al. 2008). The impact of human activities and physical processes on groundwater quality are one of the major environmental problems for sustainable development (Sharaf & Subyani 2011).

Spatial analysis of the pollutants and its associated impacts on groundwater quality is essential for a proper understanding of the present environmental problems. The GIS zonation maps prepared for each element is self-explanatory and help in future management of water resources in the area. Groundwater quality distribution maps have shown that most of the parameters are concentrated in northern and north-western parts of the region. The assessment of the spatial extent of groundwater quality, as obtained from Arc View 3.2 software analysis has revealed varying degrees of contamination in the aquifers.

The total hardness is due to the dissolved calcium and magnesium salts, usually expressed as the equivalent quantity of calcium carbonate. Concentration of hardness in water more than 200 mg/Letter can result in scale deposition. While, soft waters with a hardness of less than 100 mg/Liter have a low buffering capacity and so may be more corrosive to water pipes (WHO 2008). In groundwater quality, the hardness is usually due to carbonates, bicarbonates, sulphate and chlorides of calcium and magnesium (Venkateswara et al. 2009). The spatial distribution of total hardness (TH) in the study area (varied from 320 to 1700 mg/L. The highest values of TH are concentrated in the north-western part (Figure 6.1), which exceeded the maximum limit. The land use pattern in this part is under development.

The pH is one of the most important operational water quality parameters, although it usually has no direct impact on consumers. For effective disinfection with chlorine, the pH should preferably be less than 8.0; however, lower-pH water is likely to be corrosive. The desirable limit of pH usually ranges from 6.5 to 8.0, which is a safe range for drinking (WHO 2008). In groundwater the pH is affected by the geology of catchment area and buffering capacity of water. In the present study, the pH values were ranged from 6.8 to 8.1. In the majority of samples, the pH ranged from 7.0 to 7.8.

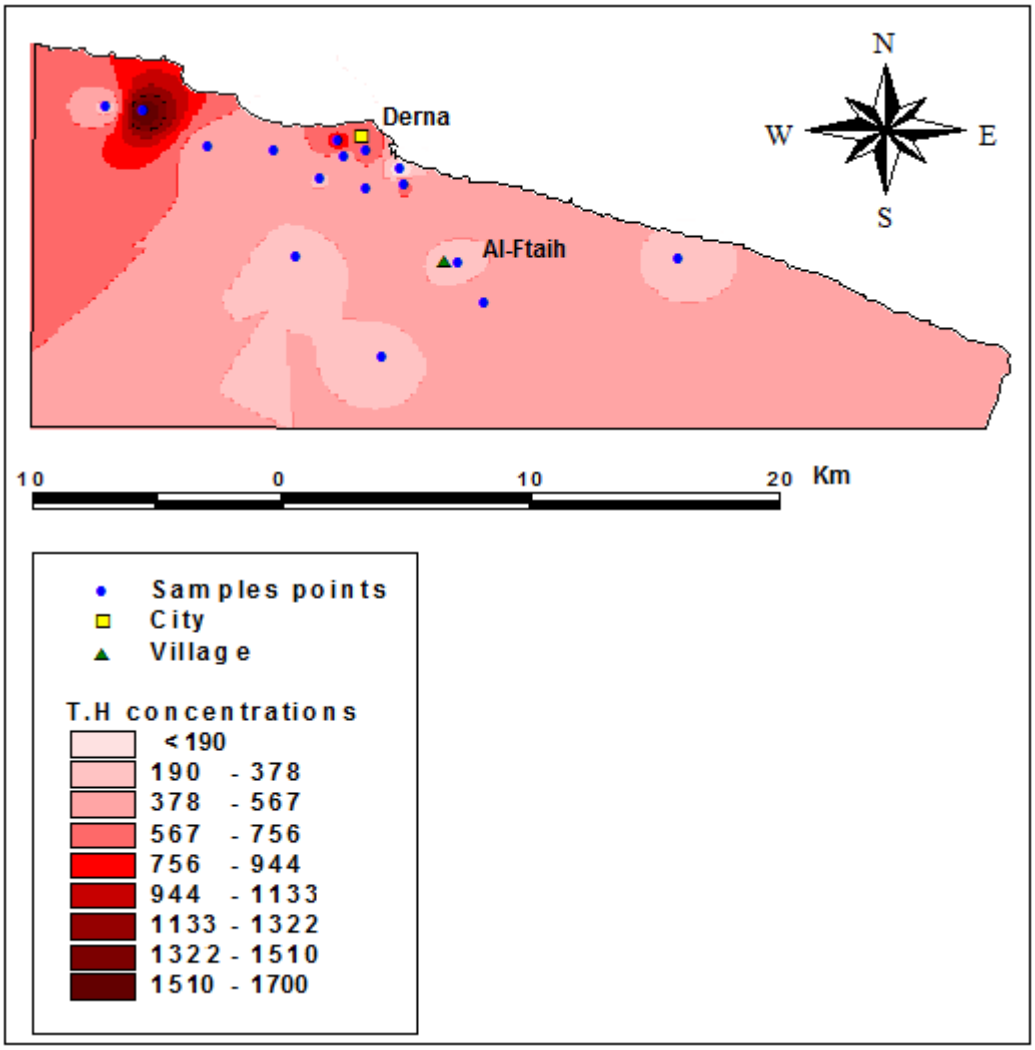

Figure 6.1 The Spatial Distribution of TH in the Region

Source: field work

. The GIS map of spatial distribution indicates that the highest value of pH (8.1) is observed in the southern part of the region in the Spring of Abu-Mansour (Figure 6.2), it is acceptable value based on the Libyan standard desirable limit which ranges between 7 to 8.5 (National Center for Standards Specification 1993).

Naturally, there are many mineral ions in groundwater. These ions slowly dissolve from geological formations as the water moves along mineral surfaces in the pores or fractures of the unsaturated zone of the aquifer. These ions are referred as dissolved solids. The total of dissolved basic components is referred as Total Dissolved Solids (TDS) concentration. Increase of cations and anions in the water means that the TDS concentration is high and thus the water becomes saline (Thomas

2003). TDS is comprised of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates with small quantities of organic matter that are dissolved in water (Bilgehan & Ali 2008).

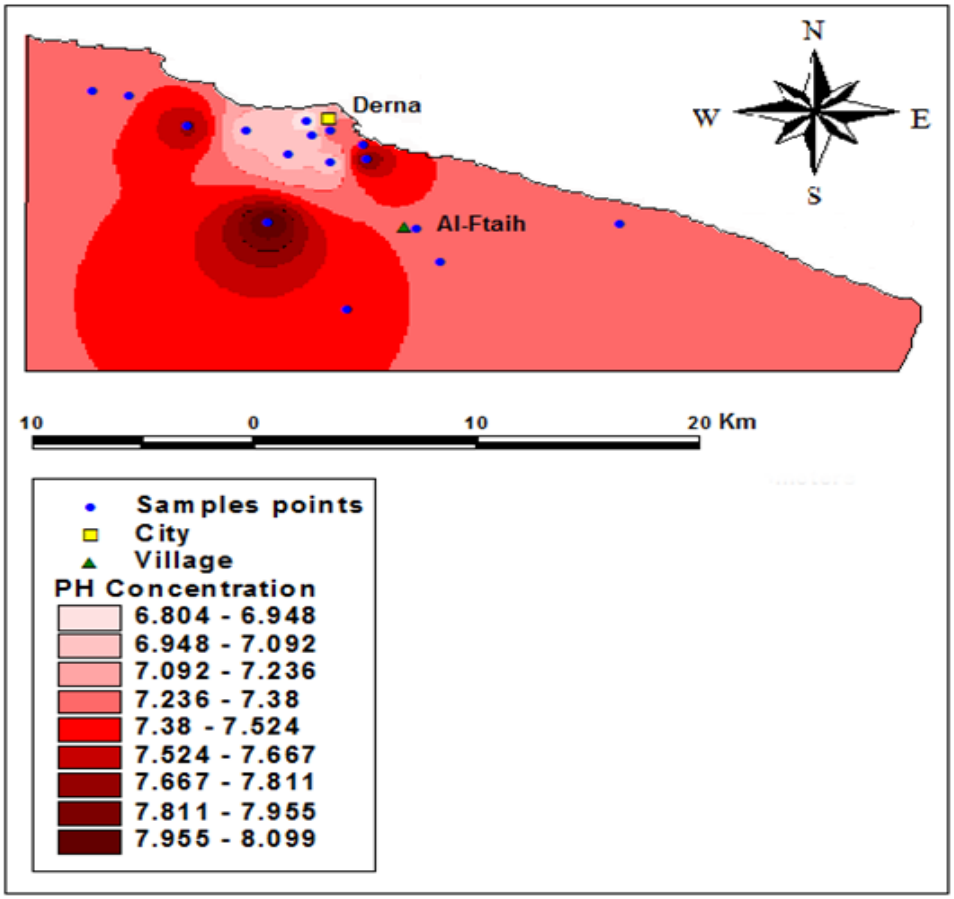

Figure 6.2 The Spatial Distribution of pH in the Region

Source: Field work 2011

In general, the TDS concentration in groundwater is not harmful to human health, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing high solids may cause laxative or constipation effects (Ramakrishnaiah et al. 2009). Most of groundwater samples in the study area have moderate concentrations of TDS and ranged between 640 mg/L and 1300 mg/L, and the TDS content was higher than the permissible limit in 35.5% of samples. The highest concentration of TDS values and that exceeded the permissible limit of drinking water, was also observed in the north-western part with 8000 mg/L and some other sporadic parts of north and east of the region (Figure 6.3). High values of TDS may be due to groundwater pollution by waste waters, which is

discharged into pits, ponds and septic tanks and migrate down the water table (Achuthan 2006). On the other hand, the increase of TDS concentration in the groundwater in most of the region parts may be due to seawater intrusion, as well as to the increase of withdrawing water, and lack of rain which compensate the lack of water especially in the dry season (Al-Taira 2004).

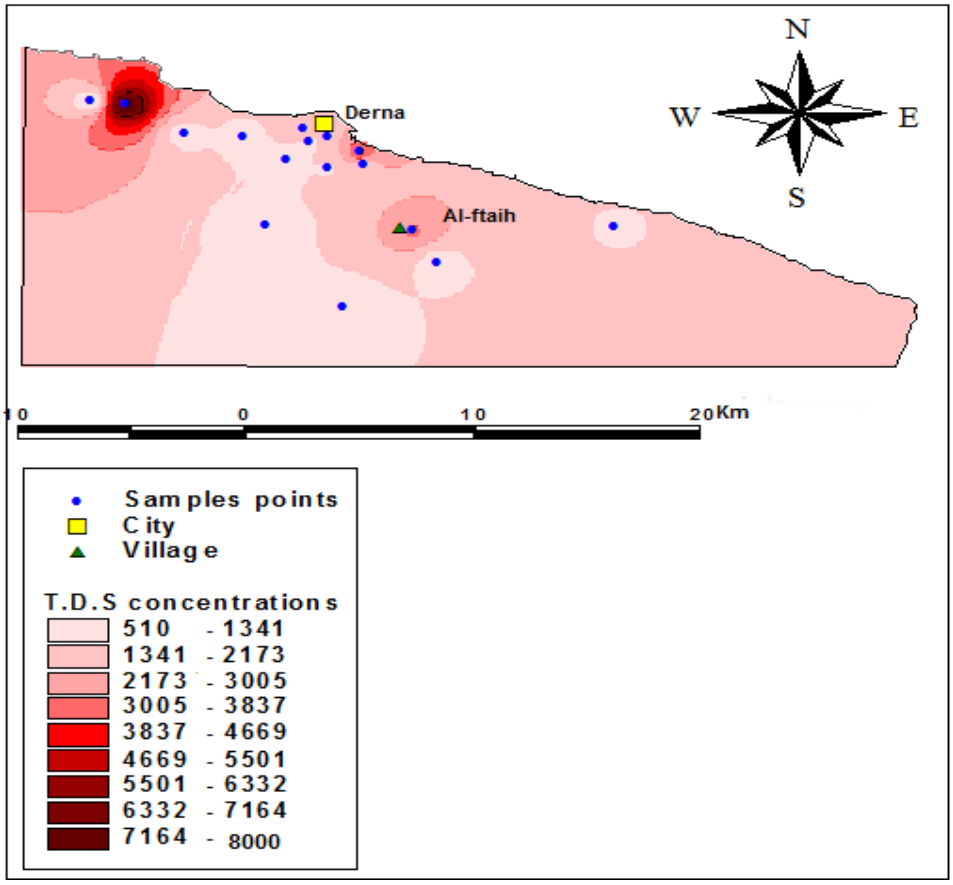

Figure 6.3 The Spatial Distribution of TDS in the Region

Source: Field work 2011

Electrical conductivity (EC) of water is a parameter related to TDS. Therefore, the EC is an indicator to represent the total concentration of dissolvable salts in water (Ramakrishnaiah et al. 2009). Pure water that is free from salts has poor conductivity. The importance of EC and TDS lies in their effect on the corrosivity of water and in their effect on the solubility of slightly soluble compounds such as $CaCO_3$ (Bilgehan & Ali 2010). Presence of salts, acids and alkalis in the water to increase its electrical conductivity. Therefore, this is used to identify the amount of

dissolved salts in water (Ghraibh & Al-Frhan, 2000). The highest values of EC are found in the north-western parts of the region and the lowest in the south and east as it is shown in (Figure 6.4). The EC values ranged between about 790 to over 12000 µS/cm.

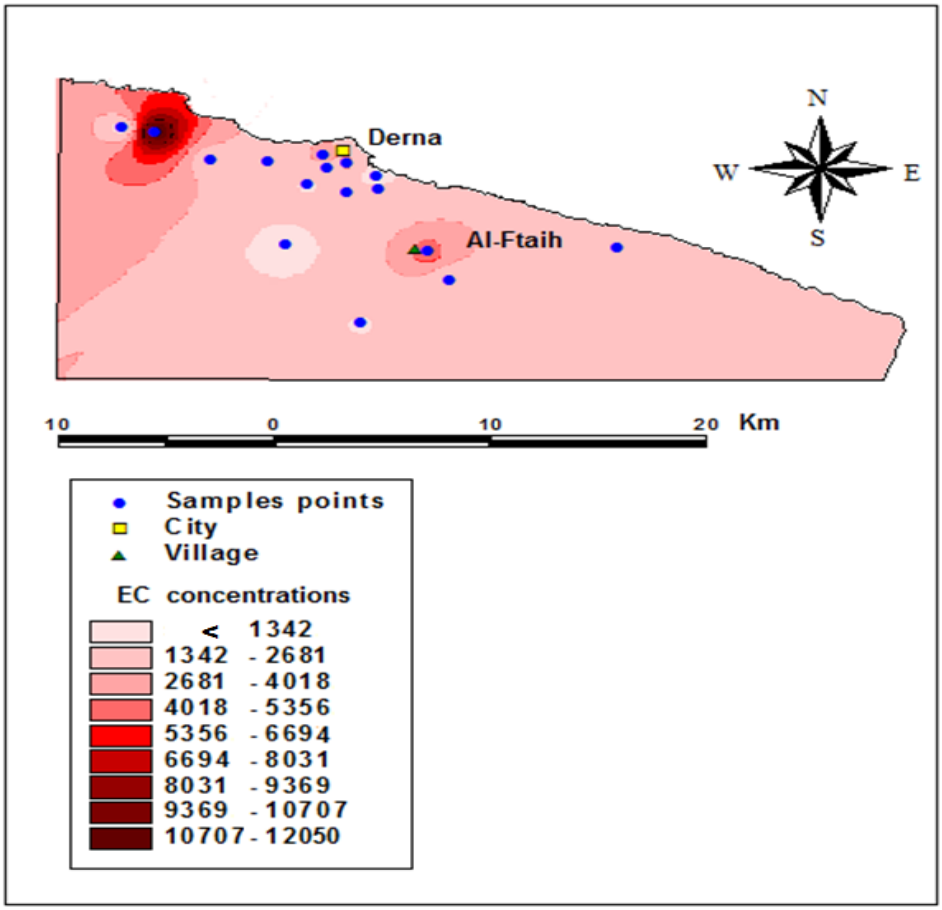

Figure 6.4 The Spatial Distribution of EC in the Region

Source: Field work 2011

Calcium is one of the most important and abundant element in the human body and an adequate intake is essential for normal growth and health. High concentration is useful and water, which is rich in calcium, is very palatable. Despite the potential health benefits of calcium abundance there are problems associated with hardness (Environmental Protection Agency 2001). The Ca++ map (Figure 6.5), indicates the presence of higher value also in the north-western part of the region with a range of 124 – 280 mg/L. The next higher range of Ca++ with 93 - 187 mg/L, have been concentrated in the central part of the city.

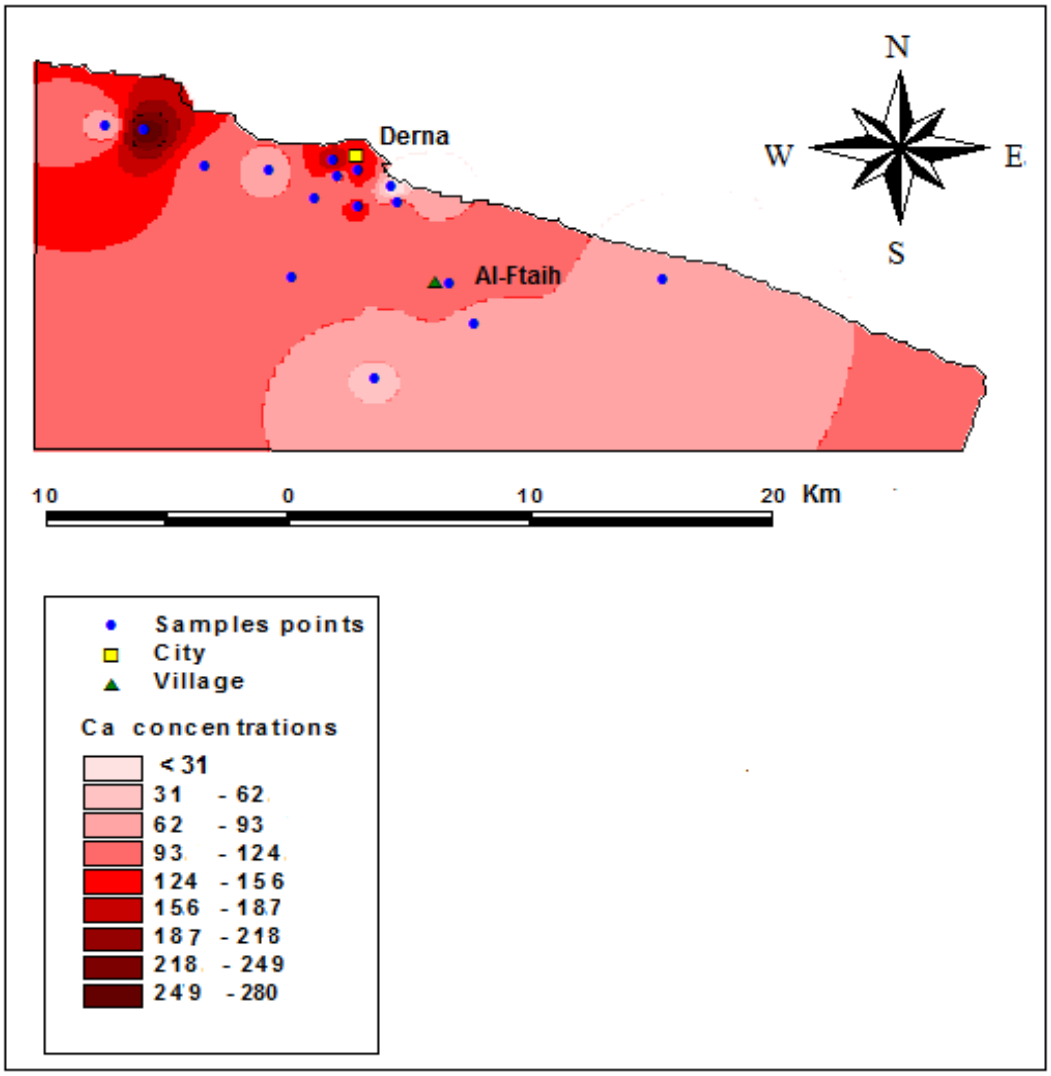

Figure 6.5 The Spatial Distribution of Ca in the Region

Source: Field work 2011

Magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day), and it is the second major constituent of total hardness with calcium (Environmental Protection Agency, 2001). Mg content, (Figure 6.6) in the study area varied from 10 to 243 mg/l. According to the National Center for Standards Specification in Libya, only 7% of samples have shown Mg above the permissible limit, and concentrated in the north-western section of the region, whereas the others were within the permissible limit.

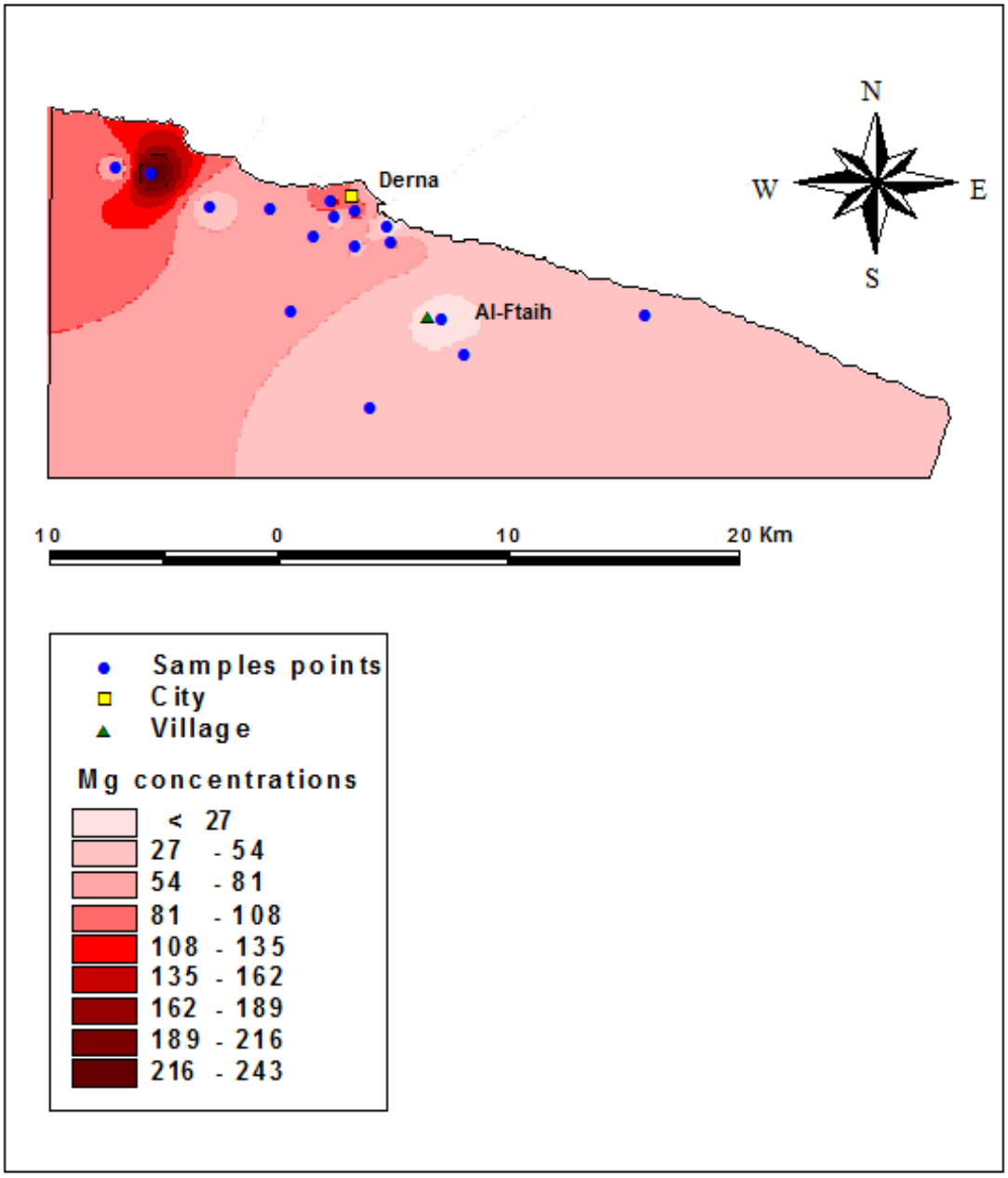

Figure 6.6 The Spatial Distribution of Mg in the Region

Source: Field work 2011

Iron exists in large quantities in the soil and rocks, mainly in the insoluble forms (Environmental Protection Agency 2001). Iron is biologically an important element, which is essential to all creatures and present in the hemoglobin. Its high concentration causes slight toxicity (Swarna & Nageswara 2010). A slightly higher concentration of the iron is found in the central and eastern part of the region (Figure 6.7). The Fe values ranged between 0 – 0.2 mg/L.

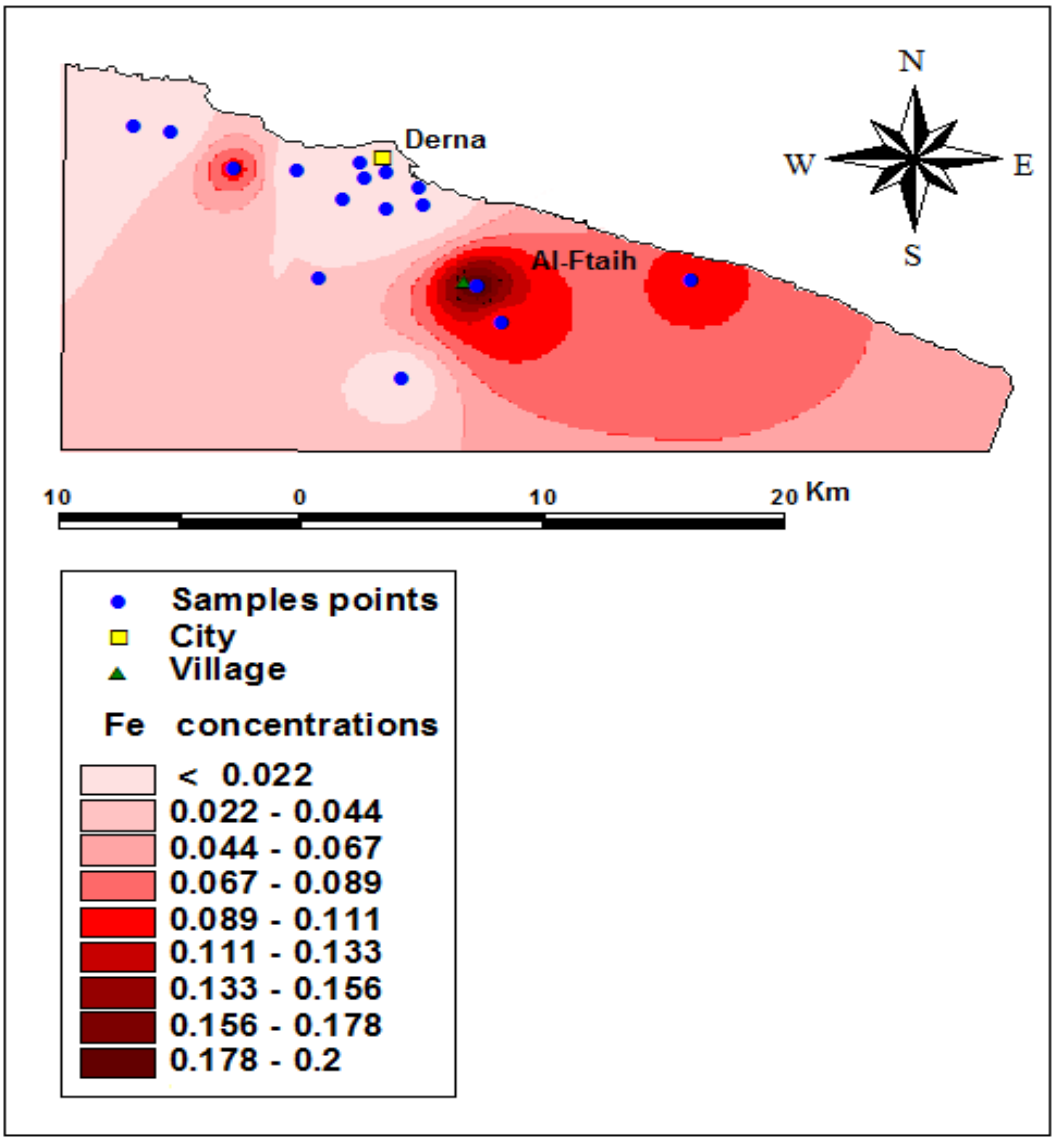

Figure 6.7 The Spatial Distribution of Fe in the Region

Source: Field work 2011

Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramines. In drinking water, ammonia is not of immediate health importance, and therefore no health-based guideline value is proposed. Its natural levels in groundwater and surface water are usually below 0.2 mg/L (WHO 2008). Based on (Figure 6.8), a slightly higher concentration of NH_4 was observed in the west of the central part of the study area, where, there is a site of solid waste dumping situated in this area. The values of NH_4 varied from 0 to 0.2 mg/L.

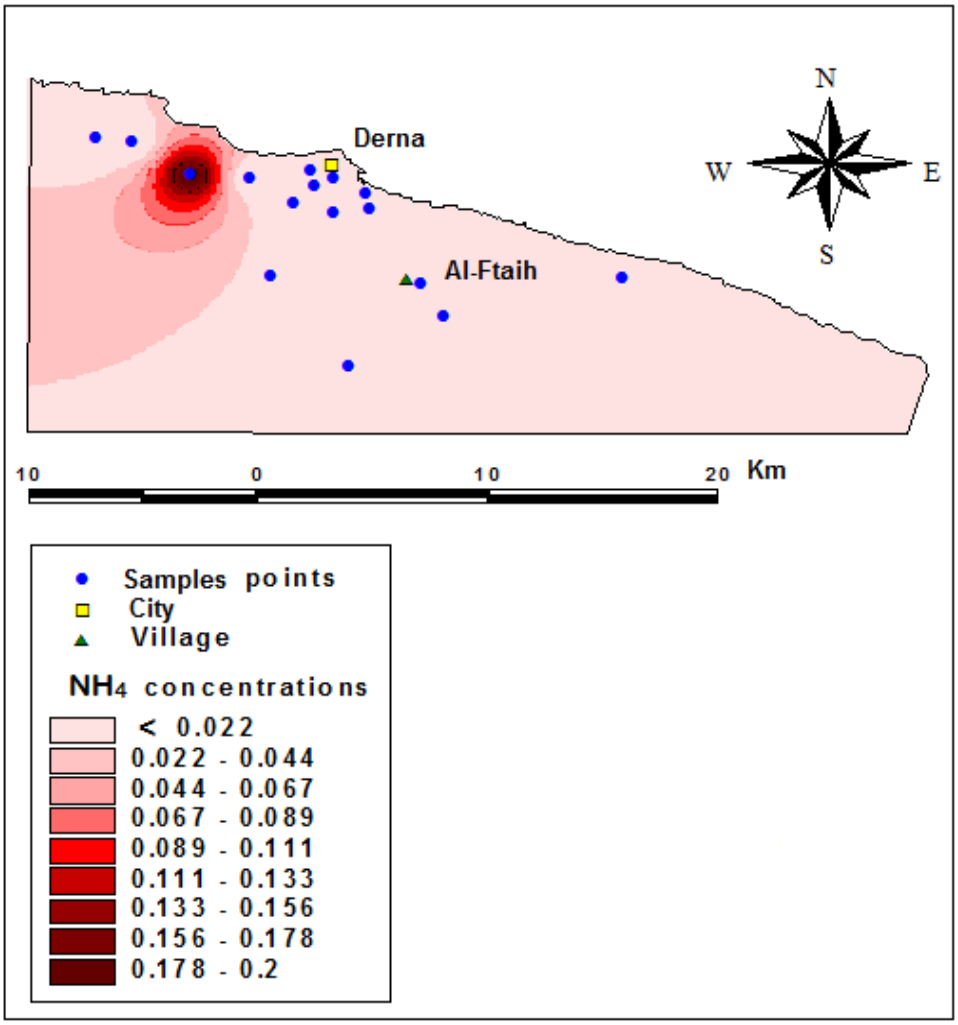

Figure 6.8 The Spatial Distribution of NH_4 in the Region

Source: Field work 2011

The Chloride is the second dominant ion in groundwater, and the higher content of it gives salty taste to the water (Venkateswara et al. 2009). Chlorides exist in all natural waters in different concentrations on a large scale. The chloride content usually increases as the mineral content increases (Bilgehan & Ali 2010). The C1 values ranged between 80 to 1140 mg/L, and it was higher than the permissible limit in about 28% of the study samples. The maximum value of C1 was observed in the western part of the region, as well as to other high averages in the centre of Derna city and the village of Al-Ftaih, (Figure 6.9). The Libyan National Centre for Standards Specification has set the permissible limit of C1 in the potable water is from 200 to 300 mg/L. In natural water, concentrations of chloride vary widely, and it is related to the mineral content of the water. As is well known, the sea water intrusion is caused

abnormal concentration of chloride, at the same time the presence of soluble chloride from rocks lead to increased Cl concentration in the groundwater. At concentrations above 250 mg/L, water acquires salty taste (Swarna & Nageswara 2010).

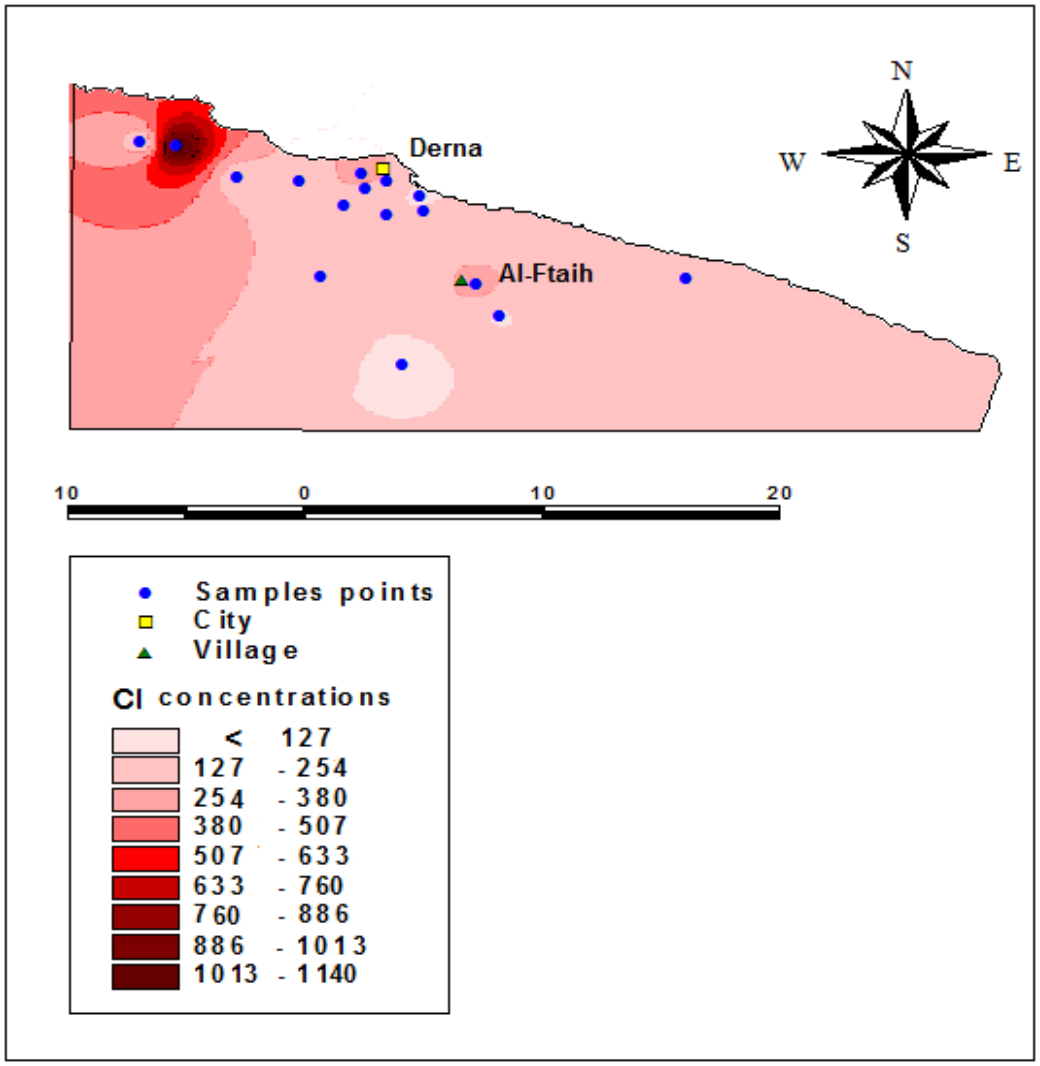

Figure 6.9 The Spatial Distribution of Cl in the Region

Source: Field work 2011

Nitrite is not usually present in significant concentrations, except in a reducing environment. It can reach both surface and groundwater as a result of agricultural activity, wastewater disposal and from the oxidation of nitrogenous waste products in human and animal excreta, including septic tanks (WHO 2008). The spatial distribution map of NO_2 (Figure 6.10) shows that the NO_2 values are ranged between

0 to 0.2 mg/L. The highest concentration was observed in the western part of Derna city, it decreases gradually to the south and east direction.

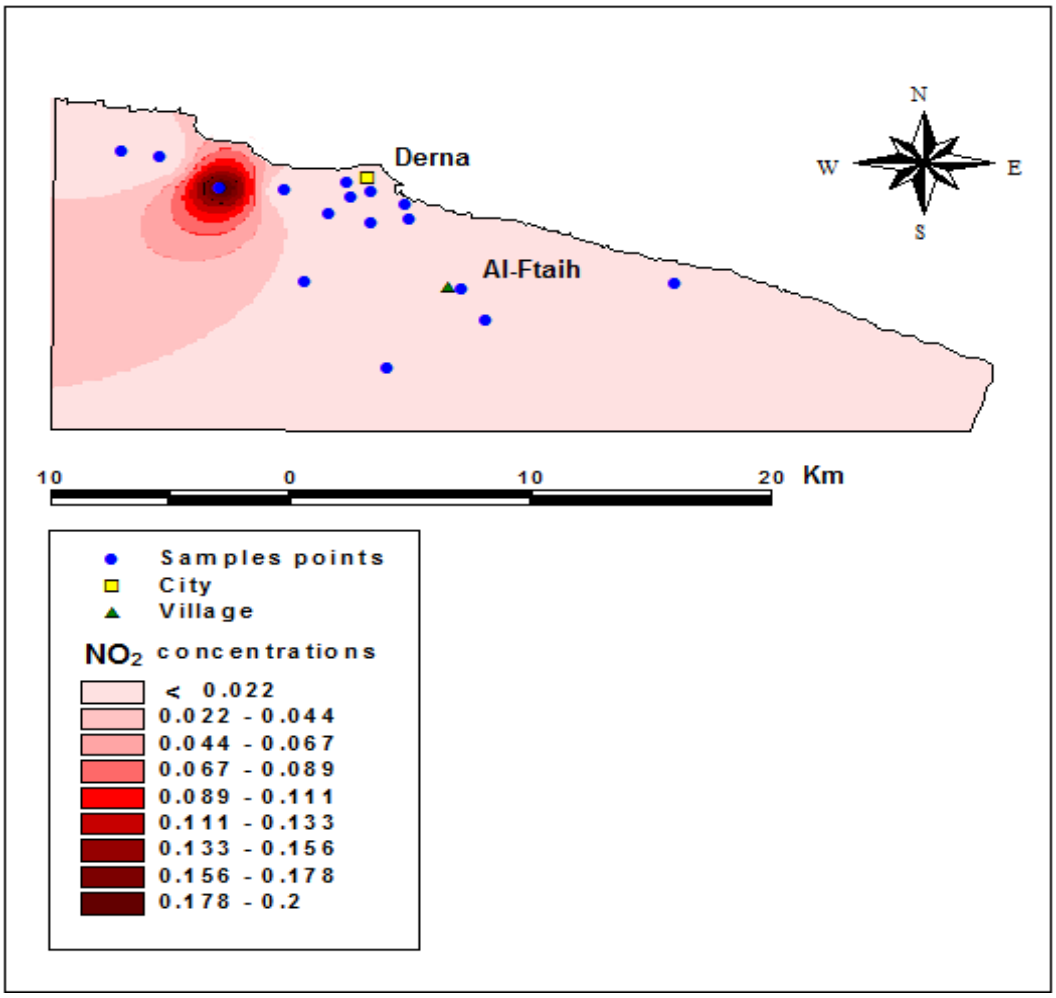

Figure 6.10 The Spatial Distribution of NO_2 in the Region

Source: Field work 2011

Phosphate is considered as an essential nutrient for living organisms occurs in water as both dissolved and particulate species (Swarna & Nageswara, 2010). It is widely used as an agricultural fertilizer and considered as a major constituent of detergents, particularly those for domestic use. Run-off and sewage discharges are the important contributors of phosphorus to surface waters (Environmental Protection Agency 200)1. PO_4 concentrations map, (Figure 6.11) shows that its values ranged between 0 to 1 mg/L. The maximum is concentrated in the west of the central and eastern parts of the Derna city (locality of Al-Maghar and Al-Sahil), whereas, the lowest concentrations were observed in the southern part of the region.

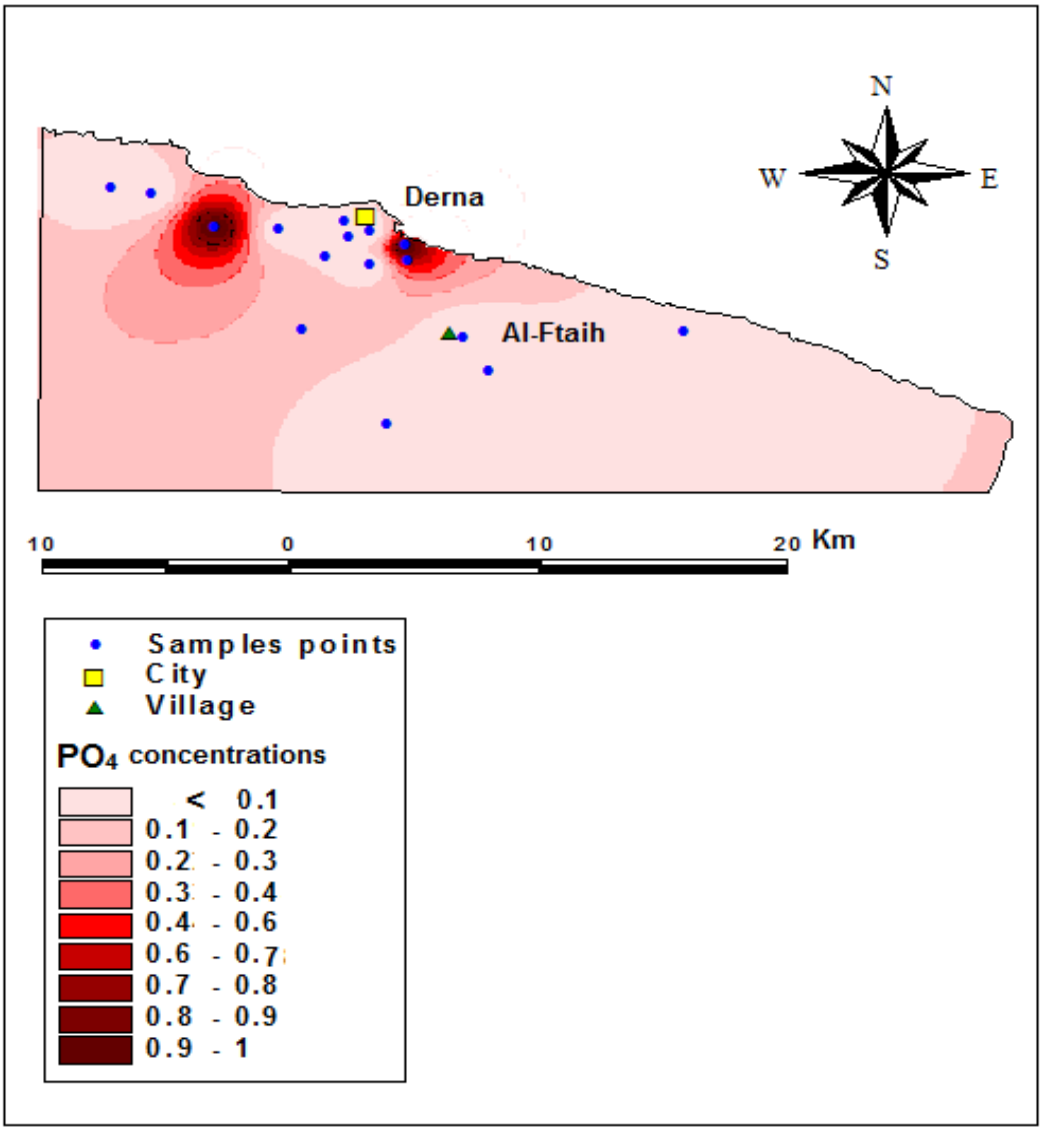

Figure 6.11 The Spatial Distribution of PO_4 in the Region

Source: Field work 2011

The spatial distribution of E. coli count varies from 0 – 100 in each 100 cm^3. The highest number of E. coli in the groundwater are concentrated in the central and western part of the Derna city, while in the southern and eastern part of the region the E. coli count has ranged between 0 to 33 in 100 cm^3 (Figure 6.12). The most spread and comparatively higher E. coli counts in the central and western part of the city of Derna indicates that the groundwater in these areas has been contaminated with human liquid waste (sewage). This may be related to the weakness of the sewage

network and the frequent presence of sewage tanks, thus overflowing the sewage and seep into groundwater reservoirs.

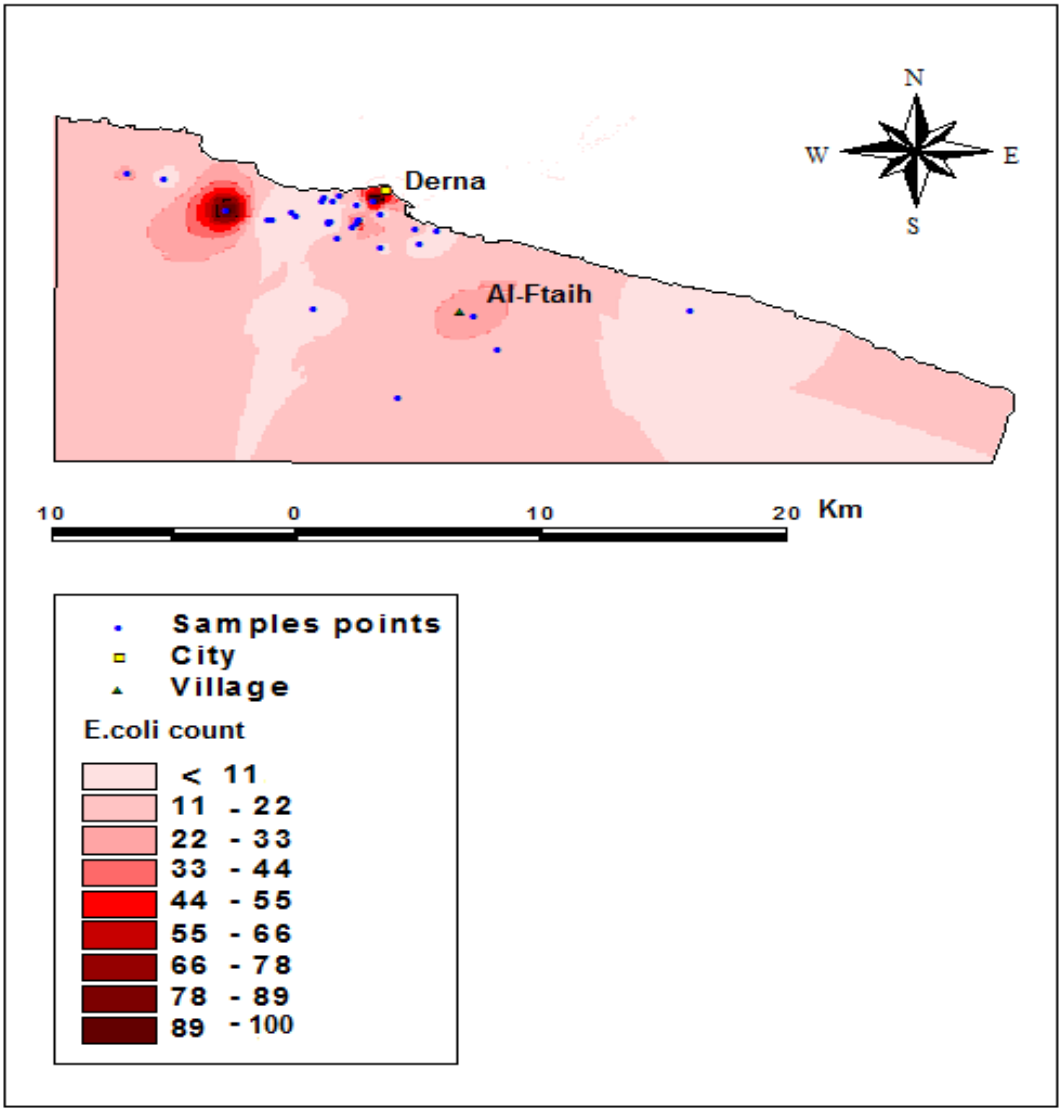

Figure 6.12 The Spatial Distribution of E. coli Count in the Region

Source: Field work 2011

6.3 WATER QUALITY INDEX (WQI)

Determining of the groundwater quality gives a clear picture about the suitability of the water for use of variety purposes. In the last few decades, due to the rapid growth of population and accelerated pace of industrialization, fresh water demand has been rapidly increased. In the developing countries, most of the agricultural activities,

especially the excessive usage of fertilizers and the improper waste disposal particularly in urban areas have affected the availability and quality of groundwater and thus threatening the human health (Ramakrishnaiah et al. 2009).

According to the World Health Organization (WHO), the polluted water caused about 80% of all human diseases. Therefore, the quality of groundwater must be healthy and regularly monitor in order to protect it. Water Quality Index (WQI) is one of the most effective tools as an information on the quality of water to concerned citizens and those who are interested on environmental affairs and thus, it becomes an important parameter for the assessment and management of groundwater (Ramakrishnaiah et al. 2009; Rajendra et al. 2009). WQI is defined as a rating reflecting the composite influence of different water quality parameters. It is calculated from the point of view of the suitability of groundwater for human consumption (Ramakrishnaiah et al. 2009). WQI serves as the basis for environmental assessment of water quality load categorization and designation of classes and beneficial uses (Munirah et al. 2011)

6.3.1 Water Quality Parameters

Groundwater quality characteristics include the physical, chemical, and biological factors of groundwater. Humans are usually most concerned with chemical and biological qualities of water (Thomas 2003). To calculate WQI of groundwater in the study area, nine chemicals and biological parameters of water were considered. These parameters are pH, Total Dissolved Solids (TDS), Total Hardness as $CaCo_3$ (TH), Calcium (Ca++) Magnesium (Mg++), Iron (Fe), Chlorides (Cl), and Phosphate (PO_4) and E. coli.

6.3.2 Water Quality Index Estimation

Water Quality Index (WQI) is a very useful and effective method for evaluating the quality of water and its suitability for drinking, also it is a very useful tool for communicating information on the overall quality of water (Asadi1 et al. 2007). WQI is calculated to reduce the large amount of water quality parameters to a single

numerical value. It reflects the composite effectiveness of different water quality parameters on the overall water quality (Swarna & Nageswara 2010).

The water quality index was calculated to determine the suitability of the groundwater for drinking purposes in the study region. In the present study WQI application has been found useful in evaluating the overall water quality. This method appears to be more systematic and gives a comparative assessment of the water quality of sampling points. On the other hand, WQI is also helpful to understand the quality of water.

On the basis of the WQI, the quality of the water is categorized from absolutely clean to severely polluted, based on (Nair et al. 2006) who did the classification in northeast Libya, (Table 6.1).

Table 6.1 Classification of Water Quality Based on WQI

WQI	Water quality	Designation
100	Absolutely clean	Class I a
80 - 99.9	Slightly polluted	Class I b
60 - 79.9	Moderately polluted	Class II
40 - 59.9	Excessively polluted	Class IIIa
0 - 39.9	Severely polluted	Class IIIb

Source: Nair et al. 2006

In the this study, the values of WQI are very much dependent upon the value of phosphate in the water. Sampling site with PO_4 reading greater than the permissible limit (0.1) mg/L occurred in two sites, indicating that the water is much polluted at those sampling sites. As mentioned in the chapter IV, the factors that have lower permissible limits are more harmful to the water quality.

Water quality index values revealed that the groundwater quality in the study area was absolutely clean water (excellent) in 14.3% only of groundwater samples; with WQI values 100, and therefore it can be used for all human consumption purposes. Slightly polluted water (good) was detected in about 64.3% of samples; with

WQI ranges between 88.50 and 99.81. Whereas, the groundwater quality in 21.4% of samples was excessively and severely polluted water (very poor) and cannot be used for domestic purposes especially for drinking. The samples were found to have high values of phosphate, iron and ammonia in the groundwater (Table 6.2).

Table 6.2 Computed WQI Values for Sampling Location

No	PH	TDS	T.H	Ca++	Mg++	Fe	C1	PO4	E. coli	WQI
1	7.0	982	400	64	58	0	140	0	0	100.00
2	7.7	950	380	96	34	0.1	180	1	100	20.63
3	7.3	640	320	64	64	0	160	0	0	100.00
4	-	8000	1700	280	243	0	1140	-	0	98.60
5	6.8	2028	900	186	116	0	360	0	0	99.32
6	7.0	942	380	88	38	0	180	0	3	99.81
7	7.4	2183	750	160	92	0	260	0	11	99.20
8	7.0	1200	560	136	53	0	160	0	29	99.21
9	7.8	1684	640	112	87	0	240	0.1	13	55.00
10	-	4000	-	-	-	0	-	1	7	25.13
11	-	750	340	56	32	0	80	0	19	98.40
12	-	1300	360	88	34	0.1	180	-	0	94.20
13	-	3100	300	104	10	0.2	300	0	33	88.50
14	-	920	550	88	31	0.1	120	-	12	93.10

Source: Fieldwork 2011

The calculated WQI values ranged from 20.63 to 100.00, and hence, the percentage of water samples can be classified into five classes from Class Ia to Class IIIb (absolutely clean to severely polluted water). The water quality index values of the well waters of the study area with their designations and quality of water are presented in (Table 6.3) and (Figure 6. 13).

The groundwater quality map was created based on the classification shown in (Table 6.3). The construction of the groundwater quality map was produced by overlapping the previous thematic maps (Figure 6.1 - 6.12), which were produced by the Inverse Distance Weighted (IDW) technique in Arc View. The WQI map (Figure 6. 14) shows the spatial distribution of the overall groundwater quality in the region. The severely and excessively polluted groundwater is found in two locations, the

central and western parts of the Derna city. The quality of water improves at the south and east, where the water quality is between moderate to slightly polluted.

Table 6.3 WQI of Groundwater in the Region and its Classes

Sample No	WQI value	Water quality	Designation
1	100.00	Absolutely clean	Class I a
2	20.63	Severely polluted	Class IIIb
3	100.00	Absolutely clean	Class I a
4	98.60	Slightly polluted	Class I b
5	99.32	Slightly polluted	Class I b
6	99.81	Slightly polluted	Class I b
7	99.20	Slightly polluted	Class I b
8	99.21	Slightly polluted	Class I b
9	55.00	Moderately polluted	Class IIIa
10	25.13	Severely polluted	Class IIIb
11	98.40	Slightly polluted	Class I b
12	94.20	Slightly polluted	Class I b
13	88.50	Slightly polluted	Class I b
14	93.10	Slightly polluted	Class I b

Source: fieldwork 2011

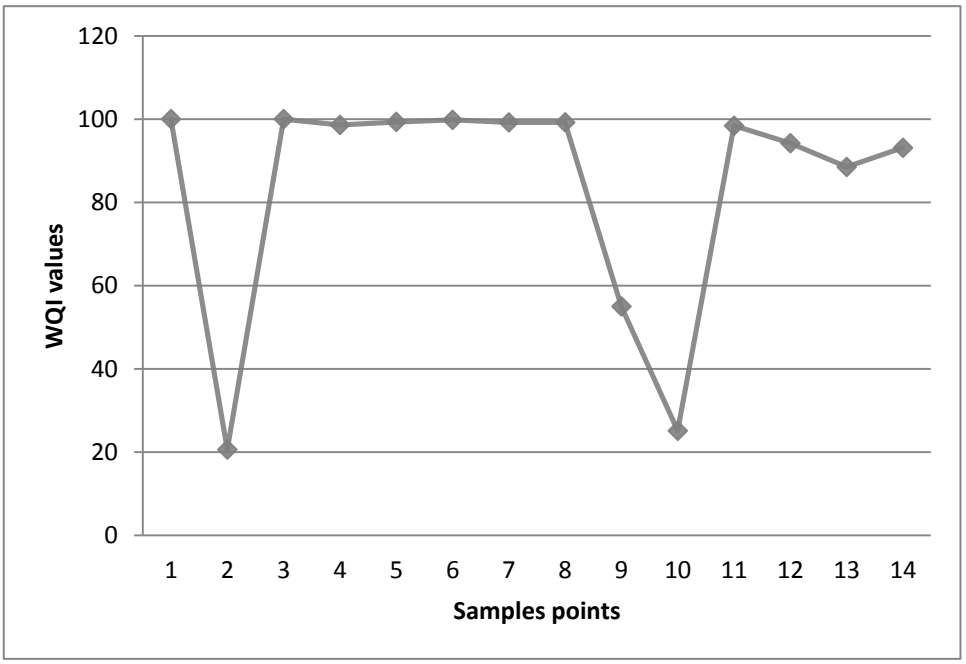

Figure 6. 13 Chart of Water Quality Index Values

Source: Fieldwork 2011

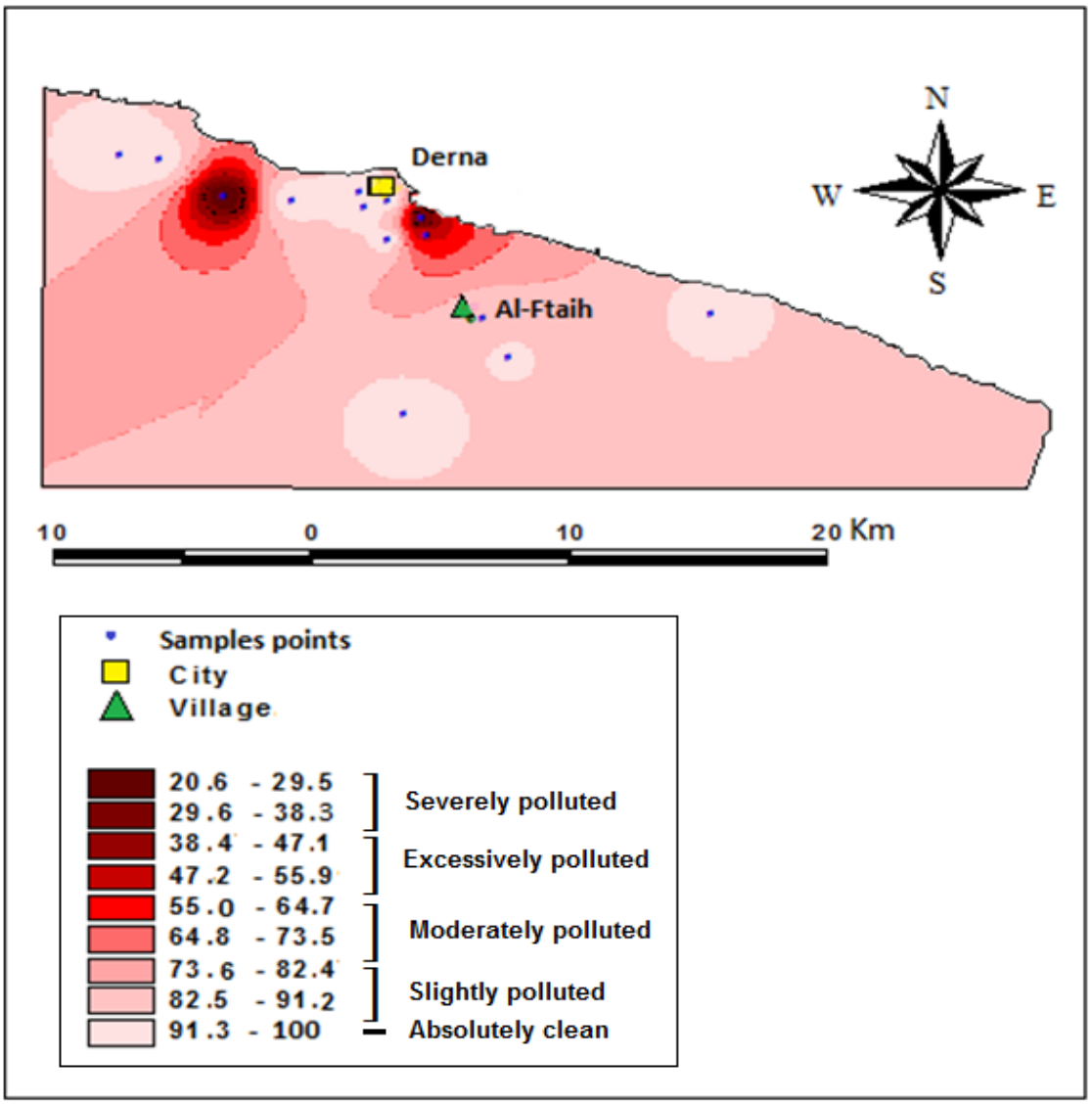

Figure 6. 14: Water Quality Index Map

Source: Fieldwork 2011

6.4 Multivariate Linear Regression (MLR)

To investigate the relationship between the water-quality parameters and their effects on the water quality index, the Multivariate Linear Regression (MLR) was employed to investigate the relationship between each of the independent variables (water quality parameters) and the dependent variable (WQI). Nine independent variables meet the entry requirement to be included in the Regression equation. These variables are: pH, TDS, T.H, Ca++, Mg++, Fe,

C1, PO_4 and E. coli. All these are parameters expressed in mg/L except pH and E. coli; where, the pH has no units and E. coli in count/100 cm^3.

This study examines the possibility of some groundwater characteristics be used in explaining the water quality index in the region of Derna. The relationships between dependent variable and independent variables are very similar to those obtained by (Hafizan et al. 2004) who have identified that , when Biochemical Oxygen Demand (BOD), Suspended Solids (SS) and Ammoniacal-Nitrate (AN) increase, the WQI is decreased and vice versa.

Initial data analysis using the Pearson correlation method was computed and presented in (Table 6.4). The analysis revealed that some of the independent variables were of medium to high positive correlation to each other, for example Ca++ is highly correlated with TH, Mg++ is highly correlated with TH and Ca++, as well as, Cl also has a strong positive relationship with TDS, TH, Ca++ and Mg++. On the other hand, the dependent variable (WQI) had an inverse correlation with some of the independent variables such as Fe, PO_4 and E. coli, implying the WQI shows a decrease when Fe, PO_4 and E. coli are increased. This indicates the possibility of using regression analysis on the data.

The summary of MLR concluded a multiple correlation coefficient (R) of 0.956 (Table 6.5) implying that there was a high relationship between the dependent variable and the set of predictors. R is similar to the r in Pearson correlation, but it has only a positive sign indicating to the strength of the relationship as a whole in spite of whether it is positive or inverse. The derived MLR of determination (R^2) is 0.914, which means that 91% of variance in the dependent variable are explained by the set of predictors.

Table 6.4 Correlation Matrix of the Variables

Variables	**WQI**	**pH**	**TDS**	**TH**	**Ca++**	**Mg++**	**Fe**	**Cl**	**PO_4**	**E. coli**
WQI	1.000	**-.023**	**-.066**	.347	.366	.307	**-.143**	.245	**-.937**	**-.602**
pH		1.000	-.439	-.005	.073	.076	-.423	-.178	-.013	.184
TDS			1.000	**.663**	**.604**	**.682**	-.054	**.830**	.088	-.193
TH				1.000	**.956**	**.963**	-.249	**.921**	-.370	-.204
Ca++					1.000	**.892**	-.115	**.886**	-.384	-.091
Ma++						1.000	-.400	**.915**	-.320	-.286
Fe							1.000	-.076	.084	**.445**
Cl								1.000	-.252	-.158
PO_4									1.000	**.598**
E. coli										1.000

Source: Field work 2011

Table 6.5 Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.956[a]	.914	.719	14.99694

a. Predictors: (Constant), E.coli, Ca++, pH, Fe, PO_4, TDS, Mg++, Cl, TH
b. Dependent Variable: WQI

Source: Field work 2011

In general, the analysis has reflected a significant regression model with F value of 4.697 at the 0.10 level. The model can be written in following form (Equation 6.1):

WQI = 108.351-1.855 pH-.007 TDS -.047 TH + .286 Ca -.186 Mg -152.587 Fe +.075 Cl -56.464PO_4 -.145 E.coli .....(6.1)

The B values explain the relationship between WQI and each parameter (Table 6.6). WQI was found to be inversely correlated with 77.8% of the water-quality parameters, and PO_4 has the greatest influence on WQI. On the other hand, it was positively correlated with only two parameters (Calcium and Chlorides). At the individual level PO_4 was the most significant variable in explaining variation in the WQI followed by Fe. Clean water quality was associated with low concentrations of pH, TDS, TH, Mg++, Fe, PO_4 and E. coli. This indicates that an increase in water quality occurs when the level of water parameters are decrease.

Liquid waste and solid waste are considered as the most important source of groundwater pollution in the region. Based on water quality index map, we have noted that the lowest groundwater quality is concentrated in the north-western and north-eastern parts of the region. The western part of the region is still under development and mostly under sporadic construction, and there is no sewage network as yet, where the liquid waste disposed in tanks as mentioned in the previous chapter. This suggests the existence of a relationship between groundwater contamination and liquid waste.

Table 6. 6 Regression Coefficients Model

Model	Unstandardized Coefficients		Standardized Coefficients	T value	Significant level
	B	Std. Error	Beta		
(Constant)	108.351	16.794		6.452	.003
pH	**-1.855**	2.458	-.245	-.755	.492
TDS	**-.007**	.009	-.452	-.756	.492
TH	**-.047**	.087	-.665	-.540	.618
Ca++	.286	.332	.681	.863	.437
Mg++	**-.186**	.614	-.398	-.302	.778
Fe	**-152.587**	149.149	-.342	-1.023	.364
Cl	.075	.110	.721	.683	.532
PO_4	**-56.464**	31.506	-.721	-1.792	.148
E. coli	**-.145**	.399	-.135	-.363	.735

a. Dependent Variable: WQI

Source: Field work 2011

On the other hand, by comparing the water quality map and the solid waste disposal map we have found that, there is a similarity and substantial convergence between them. As mentioned in the previous chapter, the main solid waste dump is located in the eastern part of Derna city, also there are two random dumps in the north-western part of the region in Al- Jubaila and Al- Mughar districts, and they are almost in the same area, where the groundwater quality is poor, whereas, the southern and southeastern parts of the region have a higher quality of water. This suggests the existence of a relationship between solid garbage and groundwater contamination.

The northern and the north-western parts of the region contain most of groundwater sources. A large part of this area has high population density. At the same time, it is located at a lower elevation, and has the most anthropogenic activities, high concentration of pit latrines and wastes. Furthermore, the surface runoff from higher areas in the south to lower

elevation areas in the north may also have contributed to the increase in pollutant concentrations, where the running water transports these pollutants, and deposits them in low-lying areas. This is similar to results obtained by (Girmay, 2010). According to the maps of water quality parameters, this area has the most number of water quality parameter contamination, whilst the quality of groundwater in the south and the southeastern parts seems to be better. This suggests that the contamination have been increased by the high population density which lacks in interest and awareness on the environment, and at the same time, the anthropogenic activities are contributing a significant role in groundwater contamination as well. As it mentioned in chapter II, the general direction of groundwater flow in the region is northward, due to the existence of faults, where the water moves in this direction. Therefore, this movement increases the concentration and the spread of pollutants in the northern parts of the region. Also at the same time, the depth of groundwater surface and the existence of limestone naturally in the geological formations in the region have played important role in speeding the access of pollutants to the aquifer and thus affecting the quality of water. Downward movement of contaminants in north area may reach the groundwater faster than those in the south area due to the variation of wells depth, where it ranges from 65 to 178 meters in the north whilst it ranges between 320 to 350 meters in the south. On the other hand, the location of the northern areas which is close to the coastline plays another role in process of seawater intrusion with the excessive withdrawal of groundwater.

6.5 CONCLUSION

This chapter contained two parts. In the first part, it discussed the spatial distribution of groundwater pollutants in the region. To achieve that, geographic information system was employed and zonation maps were produced for each element. Groundwater quality parameters distribution maps indicated that most of the contaminating parameters are concentrated on northern and north-western parts of the region except pH and iron. The quality of groundwater in the region decreases gradually to the south and east

directions. The second part focused on the suitability of the water to be used for domestic purposes based on the water quality index (WQI). The values of WQI very much depended upon the value of PO_4 in the water. The evaluation and analysis result also showed that groundwater quality in most areas is mainly in the Ib class and is not good enough to be used as potable water. But in the south and south- east portions of the region, groundwater quality is mainly good, which can be used for all human purposes. The water quality index values revealed that only 14.3% of the sample water were clean, whereas, 64.3% of samples were slightly polluted and 21.4% of samples were very polluted.

CHAPTER VII

CONCLUSION

7.1 INTRODUCTION

Provision of clean water to a population remains a major global challenge, particularly in urban areas, where a large number of people and different activities take place in a relatively smaller area, and it is one of the measures of welfare. Furthermore, lack of rainfall and sources of surface water exacerbate the problem especially in the arid and semi-arid regions.

This study addressed the issue of contamination of groundwater in the region of Derna in the northeastern part of Libya. The study focused on the key factors that cause the groundwater pollution by studying sample of the residents regarding their perceptions of the environmental situation in the region and the quality of ground water. This study also analyzed the chemical and microbiological characteristic of the water. Also , the geographic information systems (GIS) was used to determine the spatial distribution of groundwater quality. The study had successfully demonstrated that the application of GIS technique is a powerful tool in evaluating and describing the spatial analysis, and mapping of the groundwater characteristics. The study also discussed and determined the suitability of the groundwater for human consumption based on the computed Water Quality Index (WQI).

The study, which was aimed to provide information on the chemical and microbiological characteristics of groundwater quality in the region, spatial distribution of groundwater quality and its suitability for human consumption.

To reach these goals varieties of data were collected from questionnaires and groundwater samples. Where, two comprehensive questionnaires - counting on several important questions have a relationship with the subject of the study - were designed and distributed to 450 (427 in Derna city and 23 in Al-Ftaih region) respondents as a sample of the study. Thirty one groundwater sources samples were collected (wells and springs) and analyzed for; PH, Electric Conductivity (EC), Total Dissolved Salts(TDS), as well as Total Hardness(TH), Calcium (Ca++), Magnesium(Mg++), Iron(Fe), Ammonia(NH_4), Chlorides(C1), Nitrite(NO_2), Phosphate(PO_4), in additional to the Bacterial analysis (E. coli).

The groundwater samples were analyzed in the Central Laboratory in the General Water Authority, Derna to analyze the above parameters. The statistic package of social science (SPSS) program was used to analyze the data to find some of statistical relationships. The descriptive statistic and Chi square were used to identify the relationship between the groundwater pollution sources and the changes in the groundwater quality. The one - way analysis of variance (ANOVA) was applied to compare means and the differences of groundwater parameter concentrations among the region's sections, and Post Hoc test was also used to unveil the differences between the means. Multivariate Linear Regression (MLR) was employed to investigate the relationship between each of the independent variables (water quality parameters) and the dependent variable (Water Quality Index). Arc View software in Geographic Information Systems (GIS) was employed as a tool for analysis and to produce maps of the spatial distribution of concentrations of groundwater quality parameters. Also Water Quality Index (WQI) was employed to determine the water quality status and its suitability for domestic consumption.

7.2 CONCLUSION OF THE FINDINGS OF THE STUDY

7.2.1 Key Factors of Groundwater Pollution

The summary of the study discussed the key factors or the main sources of pollution of groundwater in the region of study. Which were natural and anthropogenic. The

survey conducted for analyzing the quality of groundwater and environmental conditions had identified the following factors:

a) Natural Factors

In the study area there are some natural impurity concentrations in the ground water, which depend on the nature and type of the soil, sediment and rock through which the groundwater moves, and the quality of the recharge water, as well as the distance of the region to the seawater. Excessive withdrawal of water from underground reservoirs near the coastal strip, especially those which are shallow have led to the influx of saltwater from the sea to compensate the losses in fresh groundwater, and thus the salinity of the water has exceeded standards of drinking water.

Hence, an increase in salinity rates in some of groundwater wells have been identified, especially those which are close to the coastline. About 35.1% of residents perceived that there is a significant increase in the groundwater salinity rate, 54% of them have thought that seawater intrusion as the main reason for the increase in salinity, while the remaining thought that declining groundwater level and the nature of geological formations as the key factors.

b) Anthropogenic Factors

The anthropogenic sources of pollution are the result of human activities, such as municipal, agricultural or industrial. These activities generate waste in the form of liquid, solid or gaseous, and include the followings:

I. Sewage Systems

Sewage systems are considered as the biggest source by the volume of waste and pollutants discharged to the land. The wastewater leakage in the region is either from septic tanks or through sewage network pipes and is considered as a pollution source of groundwater. Accordingly, there are two means of wastewater disposal in the region:

a. Black Reservoirs (Septic Tanks)

In the study area, most septic tanks are very poorly located, constructed and designed, and are covered only from the top. This led to the leakage of the sewage directly into ground water. Based on the survey, it was found that about 72.2% of residents rely on septic reservoirs to dispose of their wastewater, and approximately 40.5% of them did not discharge their reservoirs.

b. Sewage Networks

The sewage networks system in Derna region was established in the sixties of last century, and no longer able to accommodate the current population density of the region and become dilapidated and spills out the sewage. 67% of the population surveyed indicated that, there is an overflow of sewage from networks. This resulted in big ponds being formed of containing pollutants on the ground, which caused soil pollution and eventually leaked into the aquifer. At the same time, all sewage lift stations have been out of order and are neglected and exposed to burglary and finally have become garbage landfill. The sewage treatment plant, which was constructed in 1980, was not fully completed hence it has been left to neglect and vandalized and is now at a dilapidated stage with little actual value. All these led to leakage of sewage into aquifers.

The statistical analysis revealed that there was a significant association between the groundwater quality change and the overflowing of sewage. 75.7% of respondents have indicated that there is a significant change in the quality of groundwater in the areas that have an overflow of wastewater. The analysis yielded a chi-square value of 27.407, which was significant at the 0.05 level (P value = 0.000). Therefore, this can be concluded that there is a significant association between the groundwater quality change and the overflowing of wastewater.

II. Solid Waste and Disposal System

In the city, on the average, 70 tons or about 25,550 tons per year of solid waste are produced, which contain different kinds materials mostly organic in nature (Environmental Protection Agency 2004). The region depends on the traditional means of solid garbage disposal; the wastes are thrown in open dumps and then burnt without any processing. Furthermore, what makes matters worse is that, these dumps is not far from the residential areas, however, some dumps are on the edge of the city's border, especially in the east of the city, where the main landfill is found. Besides that, wastes are thrown on the streets, which accumulate and stack as garbage. About 65% of respondents have noticed on this problem, this happens because of the underperformance of the sanitary cleaning authority of the city and insufficient number of equipments and machineries available for the task and the lack of follow-up to the daily work of cleaning the city. These pollutants can leak with rainwater to groundwater especially when most of geological formations are limestones which allow leaks of contaminants to the aquifers.

Analysis of data showed that there was a significant association between the groundwater quality change and the accumulated solid waste in most empty places, where more than two thirds of the respondents have noticed that. Therefore, the analysis yielded a Chi-square value of 1.096 at P value = 0.295.

III. The Excessive Use of Pesticides and Fertilizers in the Farmland

The quantity of water used for agricultural purposes are estimated to be 25.6% of the total water use in the region, and this leads to decline the groundwater level and thus increase of salinity rate.

Pesticides have been widely used in the farms. The study has shown that 74% of farmers used pesticides to eliminate insects and weeds and to protect their cultivation, which in turn leak and pollute the groundwater directly or indirectly. On the other hand, 56.5% of farmers have noticed that there is a significant change in the

quality of groundwater in the agricultural areas, and most of them have used pesticides in their farms. The analysis had revealed that the Chi-square value was 4.960, which was significant at the 0.05 level (P value = 0.026). However, it can be concluded that there is a significant association between the groundwater quality change and use of pesticides.

Some of chemical compounds originating from fertilizers were reported to be the primary source of groundwater contamination. Most of the farmers in the region use many types of fertilizers, in order to improve the soil fertility and thus increase production. There were about 65% of them who use fertilizers, which affected the groundwater quality, and 80% of them had noticed that there is a significant change in the quality of groundwater. The statistical analysis had yielded that there is a significant association between the groundwater quality change and the use of pesticides, where the Chi-square value was 6.626 which was significant at the 0.05 level (P value = 0.010).

7.2.2 Quality of Groundwater in the Study Area

a) Microbiological Properties of Ground water

In the study area, the largest concern for groundwater is bacterial pollution. This may be due to the poor performance and lack of interest in the sewage management, where most of the sewage networks are on run-down state as well as relying on septic tanks in the disposal of sewage, especially in selected areas and developing neighbourhoods.

Most of water samples collected are not suitable as drinking water, because there was evidence of bacterial growth based on the Libyan standard specifications for drinking water, and at the same time it has an effect on human health. Accordingly, the source of pollution should be removed by chlorination of water according to the prescribed ratios for water treatment. In general, there was an increase in the coliform bacteria ratios, the highest recorded coliform bacteria count was 100 in each 100 cm^3, and thus it is not suitable for drinking and other human uses.

b) Chemical Properties of Groundwater

The chemical analysis showed results as the following:

a. The groundwater in the study area was neutral to slightly alkaline as its pH varies from 6.8 to 8.1.

b. The maximum value of EC was 12050 µ S/cm, and the minimum was 780 µ S/cm at the Spring of Abu-Mansour, with a mean of 2630.417 µ S/cm, this was due to the increase of salts.

c. The TDS values in some wells exceeded the permissible maximum limits with an average of 1889.923 mg/l and the maximum was 8000 mg/L. The high amount of TDS in groundwater may be due to seawater intrusion and low water level resulting from increased withdrawal and lack of rain particularly in the summer season.

d. Five wells high concentrations of TH and exceeded the allowable maximum limit, where the highest value was 1700 mg/L.

e. The Ca++ concentrations in the water samples are within allowed limits except one, which was 280 mg/L.

f. Fe, NH_4 and NO_2 concentrations were found to be more than permissible limits for drinking water in some samples.

g. One sample had very high concentration of C1 which was 1140 mg/L, and the C1 permissible limit was exceeded in about 28% of samples. PO_4 was existent in three wells.

h. The springs are almost devoid of high concentrations of chemicals that exceed the standard limit of drinking water.

7.2.3 Comparing the Means of the Concentrations of Groundwater Parameters Among the Sections in the Study Region

One-way analysis of variance (ANOVA) was used to determine the differences in the concentrations of groundwater parameters within the region. The analysis found that there were significant variations between the parameter concentrations within the region's sections, as follows:

- The average of E. coli count in the region was 16.8065 in each 100 cm^3, but the average for the eight sections seemed to be different and most of them were more than the permissible limit of the Libyan standards. The highest average was 50 counts in Al-Belad and the lowest was 6.7 in Al-Sahil, and the ANOVA analysis showed P.value of 0.814.

- The mean of TDS concentrations in the region was 1976.3571mg/L. The highest average of TDS concentration was 4320 mg/l in wells of Abu-Msafir, while the lowest was 605 mg/L in the springs. The one-way ANOVA showed a significant result with F-ratio of 0.657, which was not significant at the 0.10 level (P.value = 0 .687).

- The average of TH concentration in the region was 536.4386 mg/L, but the averages for the all sections of the region look somewhat different. The TH concentration in groundwater in three sections was found to be higher than the permissible limit of the Libyan standards. The highest average of TH concentration was 1010 mg/L and found in Abu-Msafir, whereas the lowest concentration was 295 mg/L in the springs area. The analysis of one-way ANOVA showed a significant result with F-ratio of 0.669 which was not significant at the 0.10 level (P.value = 0.680).

- The EC concentrations in the region was 2586.79 μS/cm, however, the averages for the all sections of the region did not seem to be of close approximates, where there were minor differences. The highest average of EC concentration was 7962 μS/cm in Al-Belad & Al-Jubaila in the central part of Derna city. Whereas the

lowest concentration was 219 μS/cm in the springs area. The one-way ANOVA analysis revealed that F-ratio = 0.669 which was not significant at the 0.10 level (P.value = 0.680).

- The mean of Ca concentration in the region was 112 mg/L. The highest average of Ca concentration was 172 mg/L in Abu-Msafir in the north-western part of the region. Whereas the lowest concentration was 56 mg/l in Al-Sahil in the north-eastern part of the region. The analysis of one- way ANOVA showed that the F-ratio = 0.657 at (P.value = 0 .687), it is more than the level of significance (0.10).

- The mean of Mg++ concentration in all parts of the study area was 68.92 mg/L and it was lower than the permissible limit. Most of the averages seemed to be of close approximates except two sections; the Abu-Msafir area in the north-western part of the region recorded the highest value of 153.5 mg/L, and the lowest concentration was 21 mg/L in Al-Ftaih area in the southeastern part of the region. The analysis of one- way ANOVA showed that the F-ratio = 1.064 at (P.value =.462*)*.

- The mean of Cl concentrations in all parts of the region was 266.67mg/L and it was slightly higher than the permissible limit. However, the averages for the all sections of the region seemed not to be of close approximates. The highest concentration of Cl in the region was 650 mg/L in the Abu - Msafir area, and the lowest concentration was 120 mg/L in the north-eastern part of the region. The analysis of one-way ANOVA showed that the F-ratio = .817 at (P.value =.579).

7. 2. 4 The Spatial Distribution of Groundwater Pollution

According to the GIS zonation maps, spatial distributions of groundwater parameters were as the following:

- The spatial distribution of total hardness (TH) varied from 320 to 1700 mg/L. The highest values of TH were concentrated in the north-western part of the study area, which exceeded the allowable maximum limit.

- The pH values ranged from 6.8 to 8.1. The GIS map of spatial distribution showed that the highest value of pH was 8.1 and observed in the southern part of the region in the Spring of Abu-Mansour.

- Most of TDS concentration in the groundwater samples in the region ranged between 640 mg/L and 1300 mg/L, and was higher than the permissible limit in 35.5% of samples. The highest concentration of TDS was observed in the north-western part with 8000 mg/L and some other sporadic parts of north and east of the region.

- The highest value of EC was concentrated in the north-western part of the region and the lowest in the south and east. The EC values had ranged between of 790 to over 12000 μ S/cm.

- The Ca++ map indicated the presence of the highest value also in the north-western part of the region with a range of 124 – 280 mg/L. The next higher range of Ca++ with 93 - 187 mg/L, and was found in the central part of the city.

- Mg++ values in the region varied from 10 to 243 mg/L. Only 7% of samples showed Mg++ above the permissible limit, and were concentrated in the north-western section of the region.

- There was a slightly high concentration of the Iron observed in the central and eastern part of the region. The Fe values ranged between 0 – 0.2 mg/L.

- There was a slightly high concentration of NH_4 found in the west of the central part of the study area. The values of NH_4 varied from 0 to 0.2 mg/L.

- The Cl values ranged between 80 to 1140 mg/L, and about 28% of the study samples were higher than the permissible limit. The maximum of C1 value was observed in the western part of the region, as well as at other high point in the center of Derna city and the village of Al-Ftaih.

- The spatial distribution map of NO_2 showed that the NO_2 values ranged between 0 to 0.2 mg/L. The highest concentration was observed in the western part of Derna city, it decreased gradually to the southward and eastward direction.

- PO_4 concentrations map had shown that its values ranged between 0 to 1 mg/L. The maximum was concentrated in the west of the central and eastern parts of the Derna city (locality of Al-Maghar and Al-Sahil), whereas the lowest concentrations were observed in the southern part of the region.

- The spatial distribution of E. coli count varies from 0 – 100 in each 100 cm^3. The highest number of E. coli in the groundwater were concentrated in the central and western part of the Derna city, while the E. coli count was less than 33 in 100 cm^3 southern and eastern parts of the region.

7.2.5 Water Quality Index (WQI)

Pollution status was estimated using Water Quality Index (WQI) range and water quality classes were evaluated using values of nine water quality parameter for WQI. The nine parameters are pH, TDS, TH, Ca++, Mg++, Fe, Cl, PO_4 and E. coli. The WQI values are very much dependent upon the value of PO_4 in water. The WQI values had revealed that, the groundwater quality in the region was absolutely clean in only 14.3% of the groundwater samples; with WQI values of 100. The slightly polluted in quality was found in about 64.3% of samples; with WQI ranged between 88.50 and 99.81. Lastly, the groundwater quality in 21.4% of the samples were very poor and cannot be used for domestic purposes especially for drinking.

The spatial distribution of the overall groundwater quality in the region showed that the severely and excessively polluted water are concentrated in two parts, central and western parts of the Derna city, with slightly contaminated water in the middle part. The quality of water begins to increase from south and east direction.

The statistical analysis found that, some of the independent variables were medium to high positive correlated to each other. The dependent variable (WQI) had

an inverse correlation with some of independent variables such Fe, PO_4 and E. coli, implying the WQI decreases when Fe, PO_4 and E. coli increase. The derived MLR of determination (R^2) is 0.914, which means that 91% of variations in the dependent variable are explained by the set of predictors. The analysis produced a significant regression model with F value of 4.697 at the 0.10 level. The model can be written in following form:

WQI = 108.351-1.855 pH- .007 TDS - .047 TH + .286 Ca - .186 Mg -152.587 Fe+ .075 Cl - 56.464PO_4 - .145E.coli

The B values were shown to inversely correlate with 77.8% of the water quality parameters, and PO_4 had the greatest influence on WQI. At the individual level PO_4 was the most significant variable in explaining variation in the WQI followed by Fe. Clean water quality was associated with low concentrations of pH, TDS, TH, Ma++, Fe, PO_4 and E. coli. This indicates that increase in water quality occurs when the concentrations of these water parameters were low.

7.3 RECOMMENDATIONS

Based on the findings discussed the recommendations of this study are as follows:

Avoid using shallow water wells especially near coastal areas, and cut down on the sinking wells in the region and try to find other sources of water for the region, in order to maintain the groundwater level and as well as its quality.

Laws are needed so that solid waste are not disposed of indiscriminately near sources of water and special sites should be created for the disposal of waste in a safe manner in order to maintain the environment as well as the health of human.

Empty the septic tanks and reduce sewage overflow by means of the establishment and maintenance of drainage networks in all sections of the region. And also build of sewage treatment plants.

Reduce the use of pesticides and chemical fertilizers in the farmland and use biological fertilizers instead in order to mitigate the leakage of chemical pollutants to the aquifers.

Encourage the recycling of solid wastes, and the awareness of the population regarding sorting of wastes so as to reduce the quantity and the accumulation of these wastes. Also provide the necessary modern equipments to water analysis laboratories as well as for the preparation of specialized techniques to periodically monitor the water quality sources.

REFERENCES

Abd Rahim, Md Nor. 2009. Statistical methods in research. Malaysia: rentice hall.

Abufayed, A. A. & El-Ghuel, M. K. A. 2001. Desalination process applications in Libya. *Desalination*.138 (1-3):47-53. http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6TFX-44BNGN9-7-1&_cdi=5238&_user=6470374&_pii=S0011916401002430&_orig=search&_coverDate=09/20/2001&_sk=998619998&view=c&wchp=dGLzVzb-zSkzV&md5=120817448217a6c2fded1108898d44c0&ie=/sdarticle.pdf [4 July 2010].

Abu Raya, Susan. Ahmed. 1999. Human, environment and society. Alexandria: Dar Almarifah Al jami'ah. P 15.

Adak, M. D & Purohit, K.M. 2003. Assessment of the water quality in Rajgangpur industrial complex – Part 1: Physicochemical parameters and water quality index *Pollution Research*. 22(1): 133-138. . http://direct.bl.uk/bld/PlaceOrder.do?UIN=144344400&ETOC=RN&from=searchengine [03 June 2012].

Al-Arufi, Mohammed. 1998. Terraces river and maritime jetties, a geomorphologic study in the Green Mountain area. *Scientific Magazine of Garyounis*. Excellent number. Benghazi: University of Garyounis. 333.

Al-Harram, Fathi. 1997. Geomorphologic of coast. In Al- Hadi Bologma & Saad Algzery (Ed.). *The Libyan coast book*. Benghazi: Researches and Consultations Center.

Al-Kekhia, Mansour. 1995. The population. In Al- Hadi Bologma & Saad Algzery (Ed.). *Book of Aljmaheria-a study in geography*, p. 387. Sirt: Addar Aljmaheria for Publishing and Distribution.

Al-Mabrouk, Faraj. 2003. The status of solid waste management in the city of Benghazi - the obstacles and solutions. *Seminar of recyclable and reusable solid waste*. Benghazi.

Al-Mahdawi, M. Al-Mabrouk. 1998. Geography of Libya. ed 3. Benghazi: University of Qar Younes. 85.

Al-Mansoury, Salma.1996. The city of Derna - a study in cities geographic. Master Thesis. Benghazi: University of Qar Younis. p. 16.

Al-Mashhad Al-Liby. 2010. No sewage networks in 60% of Tripoli and Benghazi and the existing are dilapidated. 27 September.

Al-Sabahi, Esmail,. Abdul Rahim, S., Wan Zuhairi, W.Y., Al-Nozaily, Fadhl. & Al-Shaebi, Fares.2009. Leachate composition and groundwater pollution at a municipal solid waste landfill of Ibb city, Yemen. *Sains Malaysiana* 38(3): 295–304. http://pkukmweb.ukm.my/~jsm/pdf_files/SM-PDF-38-3-2009/02%20 Esmail %20 Al %20 Sabah.pdf [10 Feb 2010].

Al-Siddeeq, Abu-Baker. 2000. Urban pollution of domestic solid waste in the city of Al-Bayda. Master thesis. Benghazi: University of Qar Younes.

Al-Taira, Sabab. 2004. *Groundwater pollution in the city of Benghazi.* Unpublished Master Thesis. Benghazi: University of Gar Younes.

Al-Trabelsi, Mustafa. 1999. Derna Al- Zahira. University of Derna. 12-13.

Amitha, Kommadath. 2000. Estimation of natural groundwater recharge. *Ground Water and Hydrogeology*. Section 7. http://ces.iisc.ernet.in/energy/water/proceed/section7/paper5/section7paper5.htm [18 July 2010].

Amqaily, Mohamed. 1995. Climate In Al- Hadi Bologma & Saad Algzery(ed.). *Book of Aljmaheria-a study in geography*, p. 148. Sirt: Addar Al-Jamahiriya for publishing, distribution and advertising.

Anat, Thapinta. 2002. *Use of Geographic Information Systems for assessing groundwater pollution potential by pesticides in central Thailand*. PhD theses. University of North Texas.

Arab Organization for Agricultural Development. 2010. Excessive use of chemical fertilizers. *Saline Water Conversion Corporation*. Saudi Arabia.

Asadil, S. S., Vuppala, Padmaja. & Reddy, M. Anji. 2007. Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India. *International Journal of Environmental Research and Public Health.* 4(1): 45-52. http://www.mdpi.org/ijerph/papers/ijerph2007010008.pdf [16 October 2011].

Ashour, Abu Rashed. 2008. Civil Association for the Environment Protection. Derna. Interview by an environmental windows recorder, 24 May.

Ashraf, Shahram., Afshari, Hossein. & Ebadi ,Abdol Ghaffar. 2011. Application of GIS for determination of groundwater quality suitable in crops influenced by irrigation water in the Damghan region of Iran. *International Journal of the Physical Sciences.* 6(4): 843-854.

Ashwani, Kumar. & Anish, Dua. 2009. Water quality index for assessment of water quality of River Ravi at Madhopur –India. *Global Journal of Environmental Sciences*. 8(1):49-57. http://www.globaljournalseries.com/index/index.php/gjes/article/viewFile/165/pdf [8 December 2011].

Bashir, Ahmad Bashir. 2005. The Application of Land Evaluation Technique in the north-east of Libya. PhD thesis. Cranfield University at Silsoe.

Bilgehan, Nas & Ali, Berktay. 2006. Groundwater contamination by nitrates in the city of Konya, (Turkey): A GIS perspective. *Journal of Environmental Management*. 79(1): 30-37. http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6WJ7-4H21KJC-1-S&_cdi=6871&_user=9436230&_pii=S0301479705002112&_orig=search&_coverDate=04/30/2006&_sk=999209998&view=c&wchp=dGLzVtb-zSkWA&md5=3515d2d9e3b2a8b598869dddf919592c&ie=/sdarticle.pdf [30 June 2010].

Bilgehan, Nas. & Ali, Berktay. 2008. Groundwater quality mapping in urban ground water using GIS. *Environ Monit Assess*. 160 (1-4):215–227.

Bindra, S. P., Muntasser, Moh'd., El Khweldib, Manjri. & El Khweldib, Abubaker. 2003. Water use efficiency for industrial development in Libya. *Desalination* (158): 167-178. http://www.sciencedirect.com.www.ezplib.ukm.my/science?__ob=MiamiImageURL&_cid=271370&_user=6470374&_pii=S0011916403004478&_check=y&_origin=search&_zone=rslt_list_item&_coverDate=2003-08-01&wchp=dGLbVlV-zSkWb&md5=cdc0ef90e32a37e04e1656fb91a4ff61/1-s2.0-S0011916403004478-main.pdf . [27 October 2011].

Bin Imran, Hamza., Sassi, Muhammad Ali., Abu baida, Abdel Gawad., Aldnaa, M. Mohamed., Bin Taher, Hassan Khalifa. & Makhlouf, Abdel Hamid Ramadan. No date. Works of urban development projects. Secretariat of the People's Congress of Derna popularity.

Bin Mahmud, Khalid R. & Al-Gandeel, Adnan. 1984. *Study of soil in the field.* Tripoli: Al-Fateh University.194.

Bin Mahmud, Khalid R. 1995. *Libyan soils: its composition, classification, properties and agricultural potential*. Tripoli: Al-Fateh University. 290-292.

Boukhchame, Abreik.1979. Basin of Derna Valley; a study in regional geography. Master Thesis. Cairo: Cairo University. 276.

Boulghmh, Al- Hadi. 1975. Libyan studies. Benghazi: Library of Cyrene. 75.

Boulghmh, Al- Hadi & Al-Shawi, Khalid. 1975. *Project of Jewish settlement in Cyrenaica.* Trans. Benghazi: Library of Cyrene. 61, 81,116.

Brooks, B. David. No date. Fresh water in Middle East and North Africa. In Dirk Van Damme & Bert Van Bocxlaer. *Freshwater Molluscs of the Nile Basin, Past and Present.* PP 33-64. http://www.springerlink.com/content/thu71k234x6p5280/fulltext.pdf [25May 2010].

Chung, G., Lansey, K., Blowers, P., Brooks, P., Ela,W., Stewart, S. & Wilson, P. 2008. A general water supply planning model: Evaluation of decentralized treatment. *Environmental Modelling & Software.* 23 (7):893-905 http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6VHC-4R70K7N-1-1&_cdi=6063&_user=6470374&_pii=S1364815207002022&_orig=search&_coverDate=07/31/2008&_sk=999769992&view=c&wchp=dGLbVlz-zSkWb&md5=22d33f837a5ff312df9d6a8d2253b383&ie=/sdarticle.pdf [4July 2010].

Daly, D. & Daly, E. P. 1984 *Review of nitrate in groundwater and the situation in Ireland environmental*. 491-495.

Daniel, Munga. No date. Freshwater Shortage and Groundwater Quality in Mombasa. Mombasa KMFRI.

David, J. Tonjes, Elyse O'Brien, Kim Somers. 2005. Groundwater Discharge to Long Island Marshes: Theory, Inferences, and Data. Program for the Twelfth Conference on "Geology of Long Island and Metropolitan New York. April 16.

David, W. Moody. 1996. *Sources and Extent of Groundwater Contamination.* U.S. Geological Survey: North Carolina Cooperative Extension Service. http://www.p2pays.org/ref/01/00065.htm [29 July 2010].

Demirel, Z. 2006. Monitoring of heavy metal pollution of groundwater in a phreatic aquifer in Mersin-Turkey. *Environmental Monitoring and Assessment.* 132(1-3):15-23. http://www.springerlink.com.www.ezplib.ukm.my/content/657333717h518457/fulltext.pdf [23 July 2011].

Department of meteorology. 2000. Management Of Climate And Meteorology Agricultural, Tripoli.

Doxiadis Foundation. 1967. The final report on the general plan.Derna, Municipality of Benghazi.

EL-Asswad, R.M. 1995. Agriculture Prospects and Water Resources in Libya. *Ambio,* 24 (6): 324-327.

Elaswed, Tarek., Cutler, Mark. & Duck, Robert. No date. Remote sensing of the impact of groundwater lowering on agricultural activities in the Jeffara plain, north- west Libya. University of Dundee. UK.

Elgali, Jumma A. Jumma. 2006. *Solid waste pollution in Derna city*. Unpublished Master Thesis. Benghazi: University of Gar Younes.

El-Hames, A. S., Al-Ahmadi, M. & Al-Amri, N. 2010. A GIS approach to the assessment of groundwater quality in Wadi Rabigh aquifer, Saudi Arabia. *Environ Earth Sci*. (63):1319 – 1331.

El-Saleh, Nasser & El-Seriani, Mohammad. 1979. *Quantitative and statistical geography*. Mecca: dar alfnon for publishing. p. 44.

El-Talhi, Jadallah A. 2003. *Even we do not die thirsty*. Misurata: Ad-Dar Al-Jamahiriya for publishing, distribution and advertising.

Environmental Protection Agency. 2001. Parameters of Water Quality - Interpretation and Standards. Ireland. www.epa.ie/rivermap/docs/parameters.pdf [20 October 2011].

Environmental Protection Agency. 2004. Unpublished data. Derna.

Galip, Yuce., Arzu Pinarbasi., Sakir Ozcelik. & Didem, Ugurluoglu. 2005. Soil and water pollution derived from anthropogenic activities in the Porsuk River Basin, Turkey. *Environmental Geology*. 49 (3): 359–375. http://www.springerlink.com/content/736rk8430926803p/fulltext.pdf [25May 2010].

Ghraibh, Sameh. & Al-Frhan, Yahiya. 2000. Introduction to environmental science. Amman: Dar Al-Shrouq. P: 193.

Girmay, K. A. 2010. *The impact of low cost sanitation of groundwater contamination in the city of Addis Ababa*. PhD Thesis. University Of South Africa.

Gray, N. F. 1994. Drinking Water-Problems and Solutions. John Wiley & Sons Ltd. Baffins Lane. Chichester. England.

Gualbert, H. P. Oude Essink. 2001. Improving fresh groundwater supply-problems and solutions. *Ocean & Coastal Management*. 44 (5-6): 429-449. http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6VG5-43TFJCW-B-3H&_cdi=6029&_user=6470374&_pii=S0964569101000576&_orig=search&_coverDate=12/31/2001&_sk=999559994&view=c&wchp=dGLbVzb-zSkzk&md5=a31416c34088ab441ad66a26658ce69f&ie=/sdarticle.pdf [14 July 2010].

G.W.A. 2006. Water situation in Libya. Ministry of agriculture, livestock and water. General Water Authority. Libya.

G.W.C. 2010. Unpublished data about ground water wells. General Water Company. Derna.

Habib, Aziz M. 1973. *Arab world from the Ocean to the Gulf-Libya*. Cairo: Al-Anglo Egyptian Library, p.246.

Hafizan, Juahir., Sharifuddin M. Zain., Mohd, Ekhwan Toriman., Mazlin, Mokhtar. & Hasfalina, Che. Man. 2004. Application of artificial neural model for predicting water quality index. *Jurnal Kejuruteraan Awam* 16(2): 42-55. http://www.civil.utm.my/file/file/MJCE/2004/Application%20Of%20Artificial%20Neural%20Network%20Models%20For%20Predicting%20Water%20Quality%20Index.pd [14 October 2011].

Hamad, Salah. 2008. *Spatial analysis of groundwater level and hydrochemsitry in the south Al Jabal Al Akhdar area using GIS*. Master Thesis. Salzburg University.

Ikem, A., Osibanjo,O., Sridhar, M. K. C. & Sobande, A. 2002. Evaluation of groundwater quality characteristics near two waste sites in Ibadan and Lagos, Nigeria. *Water, air, and soil pollution.*140 (1-4): 307-333. http://www.springerlink.com/content/x177xk2734877103/fulltext.pdf [25 May 2010].

Industrial Research Center. 1984. *Geological map of Libya (250000: 1) sheet of Derna, explanatory booklet*. Tripoli. 3.

Ismail, Anwar. 1998. *The water deficit in the Derna Valley* .Master Thesis. Benghazi: Gar Younis University . 99.

IWRM. 2007. *Current Status and the Way Forward Demonstrated by National, Regional and International Experiences*. Workshop Summary and Recommendations. 11-12 April 2007, Integrated Water Resources Management in Libya. Tripoli.

James, A. Entry & Neal, Farmer. 2001. Ground Water Quality- Movement of Coliform Bacteria and Nutrients in Ground Water Flowing through Basalt and Sand Aquifers. *J. Environ. Qual*. 30:1533–1539.

James, E. McGreevey., Bradley, M. Campbell., Ernest, P. Hahn. & Larry, Baier. 2004. *New Jersey Storm water Best Management Practices Manual*. New Jersey Department of Environmental Protection. Division of Watershed Management.

James, P. Hall. 2004. Development of an implementation plan for a geographic information system: case of Lincoln County. *International Journal of Information Management*. 24(3): 267-275. http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6VB4-4C4W1C7-3-1&_cdi=5916&_user=6470374&_pii=S0268401204000349&_orig=search&_coverDate=06/30/2004&_sk=999759996&view=c&wchp=dGLzVtz-zSkWb&md5=afaa3ea151e242fb104cd613bbdf1e07&ie=/sdarticle.pdf [30 June 2010.

Jawda, Jawda. Hasanein. 1998. *The natural geography of the Arab world deserts*. Alexandria: Munshaat Almaaref. 323.

Kathleen, M. Wolfe. 2008. *GIS as an Investigative Tool: Groundwater Contamination and Private Wells in Guilford County, North Carolina*. Master thesis. Faculty of the Graduate School, University of North Carolina.

Keswick, BH. 1984. Sources of Groundwater Pollution. In John Wiley and Sons (ed). *Groundwater Pollution Microbiology*, pp. 39-64. New York.

Larry, W. Canter. & Robert, C. Knox. 1988.Septic tank system effects on ground water quality. Lewis publisher INC.2,13. Chelsae-Michigan.

Lenntech. no date. Water Treatment Solution. *Sources of groundwater pollution.* Netherlands. http://www.lenntech.com/groundwater/pollution-sources.htm [10. May 2011].

MacDonald, A.M. & Calow, R.C. 2009. Developing groundwater for secure rural water supplies in Africa. *Desalination* 248 (1-3) 546–556. http://www.sciencedirect.com.www.ezplib.ukm.my/science?_ob=MImg&_imagekey=B6TFX-4XC50FY-2N-1&_cdi=5238&_user=6470374&_pii=S0011916409006316&_orig=search&_coverDate=11/15/2009&_sk=997519998&view=c&wchp=dGLzVtb-zSkzS&md5=517fdda31607064991fe17960f9c5850&ie=/sdarticle.pdf [4 July 2010]).

Mahfouz, Salem A., Shaieb, F. M. & Elzen, A.E.K. 2008. Detection and identification of groundwater bacteria in Sebha City, Libya. *African Journal of Microbiology Research.* 2: pp. 224-228. http://www.academicjournals.org/ajmr (12 Mar 2010).

Malti, Saad. Kustandi. 1995. Al-Marj Territory Climate. *Journal of the Faculty of Arts*. University of Benghazi. (7): 248 – 249.

Mevlut, Uyan & Tayfun, Cay. 2010. Geostatistical methods for mapping groundwater nitrate concentrations. 3rd international conference on cartography and GIS. 15-20 June, 2010. Nessebar, Bulgaria.

Ministry of Agriculture.1980. Tripoli. Libya.

Mukul, Bishnoi & Ravinder, Malik. 2008. Groundwater quality in environmentally degraded localities of Panipat city, India. *Journal of Environmental Biology.* 29(6): 881-886. http://www.jeb.co.in/journal_issues/200811_nov08/paper_14.pdf [25 May 2010].

Munirah Abdul Zali., Ananthy Retnam., Hafizan Juahir., Sharifuddin M. Zain., Mohd Fadhil Kasim., Baharuddin Abdullah.& Syaiful Bahren Saadudin. 2011. Sensitivity Analysis for Water Quality Index (WQI) Prediction for Kinta River, Malaysia. *World Applied Sciences Journal.* 14 (Exploring Pathways to Sustainable Living in Malaysia: Solving the Current Environmental Issues): 60-65.

Nair, G. Achuthan., Bohjuari, Jalal Ahmed., Al-Mariami, Muftah A., Attia, Fathi Ali. & El-Toumi, Fatma F. 2006. Groundwater quality of north-east Libya. *Journal of Environmental Biology.* 27(4) 695-700. http://jeb.co.in/journal_issues/200610_oct06/paper_15.pdf [19 October 2011].

National academy of science. 2008. *Safe drinking water is essential. fossil water in Libya*. http://www.drinking-water.org/html/en/Sources/Fossil-Water-in-Libya.html [5 July 2010].

National Authority of Information and Documentation.1954, 1964, 1973, 1984, 1995, 2006. Final results of the General Census of Population. Tripoli.

National Center for Standards Specification. 1993. Libyan standard specification number 82, drinking water. *Journal of Engineering*.(25-26): 96-98.

Nofal, Hassan. Mohammed. 1991. The urban environment and the dangers of pollution. *Assiut Journal for Environmental Studies*. 1. 73.

Oliver, Worm & Katja, Vaupe. 2008. The Dirty Portfolios of the Pesticides Industry-Product Evaluation & Ranking of Leading Agrochemical Companie. Hamburg: Greenpeace. http://www.greenpeace.org/raw/content/eu-unit/press-centre/reports/dirty-portfolios-of-pesticides-companies.pdf [9 September 2011].

Paras, R. Pujari. & Vijaya, Deshpande. 2005. Source Apportionment of Groundwater Pollution around Landfill Site in Nagpur, India. *Environmental Monitoring and Assessment.* 111(1-3):43-54. http://www.springerlink.com.www.ezplib.ukm.my/content/y274522318668j14/fulltext.pdf [25 May 2010].

Passarella, G., Vurro, M., D'agostino, V., Giuliano, G. & Barcelona, M. J. 2002. A probabilistic methodology to assess the risk of ground water quality degradation. *Environmental Monitoring and Assessment*. 79(1):58-75. http://www.springerlink.com.www.ezplib.ukm.my/content/g2011t0g8q1u5840/fulltext.pdf [25 May 2010].

Pradeep, K. Naik., Biranchi, N. Dehury. & Arun. N. Tiwari. 2006. Groundwater pollution around an industrial area in the coastal stretch of Maharashtra State, India. *Environ Monit Assess.* 2007 (132):207–233. http://www.springerlink.com/content/v3086415716511m2/fulltext.pdf [25 May 2010].

Rajendra D. S. Prasad, C. Sadashivaiah & G. Ranganna. 2009. Water Quality Index and Regression Models for Predicting Water Quality and Water Quality Parameters for Tumkur Amanikere Lake Watershed, Tumkur, Karnataka, India. *The Green pages*. http://www.eco-web.com/edi/index.htm [22 October 2011].

Reide, D. Corbett., William, C. Burnett. & Jeffrey, P. Chanton. 2009. *Submarine Groundwater Discharge: An Unseen yet Potentially Important Coastal Phenomenon.* University of Florida.

Roger, Calow & Alan, MacDonald. 2009. *Background Note, What will climate change mean for groundwater supply in Africa*. Overseas Development Institute & the British Geological Survey http://www.odi.org.uk/resources/download/3150.pdf [4 July 2010].

Ramakrishnaiah, C. R., Sadashivaiah, C. & Ranganna, G. 2009. Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. *E-Journal of Chemistry*. 6(2), 523-530. http://ejchem.net/PDF/V6N2/523-530.pdf [24 October 2011].

Sacchidananda, M. & Prakash, N. 2006. *Groundwater pollution and emerging environmental challenges of industrial effluent irrigation:* a case study of Mettupalayam Taluk, Tamil Nadu. Madras school of economics. Gandhi Mandapam Road Chennai 600 25.India. http://www.iwmi.cgiar.org/assessment/files_new/publications/discussion%20paper/cadiscussionpaper4.pdf [13 March 2010].

Salem, Omar. (No date). Management of Shared Groundwater Basins in Libya. *AfricanWaterJournal.*1(1):106-117. http://www.uneca.org/awich/awj_vol1_no1/7%20management%20of%20shared%20groundwater%20basins%20in%20libya.pdf [25 May 2010].

Saline Water Conversion Corporation. 2010. *Warning against excessive use of chemical fertilizers in agricultural production*. Arab Organization for Agricultural Development. Saudi Arabia.

Schmidt, A., Gibson, J. J., Santos, I. R., Schubert, M., Tattrie, K. & Weiss, H. 2010. The contribution of groundwater discharge to the overall water budget of two typical Boreal lakes in Alberta/Canada estimated from a radon mass balance. *Hydrology and Earth System Sciences.* (14):79-89. www.hydrol-earth-syst-sci.net/14/79/2010/ [25 July 2010].

Sebastien, Lamontagne., Corinne, Le Gal La Salle., Craig, Simmons., Julianne, James-Smith., Nikki, Harrington., Andrew, Love., Anthony, Smith., Gary, Hancock. & Howard, Fallowfield. 2005. Estimation of groundwater and groundwater discharge to the Adelaide Coastal Waters Study area. Technical Report, South Australian Environment Protection Authority.

Shahin, Mamdouh. 2007. Water Resources and Hydrometeorology of the Arab Region. *Water Science and Technology Library*. 59: 369-443. http://www.springerlink.com/content/u116587h5t26k320/fulltext.pdf. [25May 2010].

Sharaf, Abdul-Aziz .1996. *Geography of Libya.* Alexandria: Center of Researches for Book. 127.

Sharaf, Abdul-Aziz. 2000. *Environmental pollution- its present and future*. Alexandria: Alexandria Center for book . 127-128.

Sharaf, Mohammed Amin. M. & Subyani, Ali M. 2011. Assessing of Groundwater Contamination by Toxic Elements through Multivariate Statistics and Spatial Interpolation, Wadi Fatimah, Western Arabian Shield, Saudi Arabia. *International Journal of Scientific & Engineering Research* 2(9). http://www .ijser.org [27 September 2011].

Sophocleous, M. (2004), Groundwater recharge. In Luis Silveira, Stefan Wohnlich & Eduardo J. Usunoff (ed). Groundwater in Encyclopedia of Life Support Systems (EOLSS). Developed under the Auspices of the UNESCO, Eolss : Oxford. http://www.eolss.net [18 July 2010].

Srikanth, Satish Kumar Darapu., Sudhakar, B., Krishna, K. Siva Rama., Rao, P. Vasudeva. & Sekhar, M. Chandra. 2011. Determining Water Quality Index for the Evaluation of Water Quality of River Godavari. *International Journal of Engineering Research and Applications (IJERA)* 1(2):174-182. www.ijera.com /papers/ vol% 201%20issue%202/012174182T.pdf [20 October 2011].

Suleiman, Khalil A. 1992. Ground water pollution. *Environmental Journal*. Tripoli: public organization of environment.(20):3-5.

Suleiman, Khalil A. 1993. Ground water pollution. *Journal of Engineering*. (25-26): 100-101.

Swarna, Latha. P & Nageswara, Rao. K. 2010. Assessment and Spatial Distribution of Quality of Ground Water in Zone-II and III, Greater Visakhapatnam, India Using Water Quality Index (WQI) and GIS. *International Journal of Environmental Sciences.* 1(2):198-212. http://ipublishing.co.in/jesvol1no 12010/EIJES 1019.pdf [12 October 2011].

Taghizadeh, Mehrjardi R., Zareian, Jahromi. M., Mahmodi, Sh. & Heidari, A. 2008. Spatial Distribution of Groundwater Quality with Geostatistics (Case Study: Yazd-Ardakan Plain). *World Applied Sciences Journal* 4 (1): 09-17. http://idosi.org/wasj/wasj4(1)/2.pdf [27 September 2011].

Tandel, Bhaven N., Macwan, Jem. & Soni, Chirag. K. No date. Assessment of Water Quality Index of Small Lake in South Gujarat Region, India. South Gujarat University. India.

Thomas, Harter. 2003. *Groundwater quality and groundwater pollution.* University of California, Division of Agriculture and Natural Resources. http://groundwater.ucdavis.edu/Publications/Harter_FWQFS_8084.pdf [29 July 2010].

UNESCO. 2002. Ground water contamination inventory. A methodological guide. IHP-VI, series on ground water no.2. United Nations Educational, Scientific and Cultural Organization.

Venkateswara, Ch. Rao., Sankar, M. Ravi. & Prakasa, B.S. Rao. 2009. Spatial distribution of ground water quality information at Rajahmundry and its surrounding areas - GIS approach. Seminar on Spatial Information Retrieval, Analysis, Reasoning and Modeling. ISI-DRTC, Bangalore, India 18-20 March.

Water Encyclopedia. No date. Pollution of Groundwater. Science and Issues. (Online) http://www.waterencyclopedia.com/Oc-Po/Pollution-of-Groundwater.html.

W.H.O.2008. Guidelines for drinking water quality. 3rd edition Vol. 1 Recommendations. Geneva. World Health Organization. http://www.who.int/water_sanitation_health/dwq/fulltext.pdf [20 October 2011].

Wikipedia. (2010). Groundwater discharge. http://en.wikipedia.org/wiki/Groundwater_discharge [23 July 2010].

Wilhelm, Struckmeier., Yoram, Rubin. & Jones, J. A. 2005. Groundwater - reservoir for a thirsty planet. Leiden, the Netherlands: Earth Sciences for Society Foundation.

William, R. Mason. 2010. Pollution of Groundwater. Water Encyclopedia. Science and Issues. http://www.waterencyclopedia.com/Oc-Po/Pollution-of-Groundwater.html [29 July 2010].

Zain Al-Abideen, Ali & Arafat, Mohammed. 1992. Environment pollution price of civilization. Cairo: academic library.190.

Zaporozec, A. 1981. Ground-Water Pollution and its Sources. *GeoJoumal*. 5(5): 457-471.

APPENDIXES

APPENDIX A

A QUESTIONNAIRE ABOUT GROUNDWATER QUALITY OF AGRICULTURAL AREA IN THE REGION

Form no ☐

1. Age: ☐

2. Education level: a. Primary ☐ b. Preparatory ☐
   c. Secondary ☐ d. High education ☐

3. Occupation: ……

4. Monthly income: ☐ LD

5. Farm size: a. less than hectare ☐ b.1-10 hectares ☐ c. 11-20 hectares ☐
   d. 21-30 hectares ☐ e. more than 30 hectares ☐

6. Farm location:
   a. at the valley ☐
   b. at the plain area ☐
   c. at the slope area ☐

7. The soil in the farm: a. red clay soil ☐ b. Rocky soil ☐ c. sediment soil ☐
   d. sandy soil ☐ e. others(specific) ☐

8. Type of agriculture: a. irrigated ☐ b. rain fed ☐ c. both ☐

9. Type of produced crops: a. fruits ☐ b. vegetables ☐
   c. grains ☐ d. others ☐

10. Is there any industrial activities nearby the farm? a. yes ☐ b. no ☐

11. If yes, what is the activity type?
    a. ……..……
    b. ..... ……

12. How many km between the farm and the industrial activity? km ☐

13. Uses of well water in the farm: a. for drinking ☐ b. for agriculture ☐
c. for watering animals ☐ d. all of them ☐

14. Type of well: a. surface ☐ b. deep ☐

15. Production capacity of the well: ☐ m^3/day

16. Quality of the water in the well: a. fresh ☐ b. salty ☐
c. poor ☐

17. Color of the water: a. pure water ☐ b. turbid water ☐

18. Is there a station for sewage treatment? a. yes ☐ b. no ☐

19. If yes, how far from the well? ☐

20. Are there septic tanks nearby your farm? a. yes ☐ b. no ☐

21. If yes, how far from the well? ☐

22. Do you add Chlorine or Fluorine to the water in the well?
a. yes ☐ b. no ☐

23. If yes, why? .....

24. Do you use the pesticides to eradicate the pest? a. yes ☐ b. no ☐

25. If yes, when. a. Daily ☐ b. Weekly ☐ c. Monthly ☐
d. Annually ☐ e. When necessary ☐

26. What the amount of pesticides that used in one hectare. ☐ Kg

27. Do you use agricultural fertilizers? a. yes ☐ b. No ☐

28. If yes, what kind of them do you use?
…….....

29. Is there a garbage dump nearby the wells? a. yes ☐ b. no ☐

30. Are there processes of chemical and biological analysis to detect the viability of water for human use? a. yes ☐ b. no ☐

31. If yes, when. a. daily ☐ b. weekly ☐ c. monthly ☐
d. annually ☐ e. when necessary ☐

32. Have you noted that there is a change in the water quality and quantity in recent years?

a. yes ☐ b. no ☐

33. If yes, what are the effecting reasons do you think?

a) ……..
b) ……..
c) ……..

34. What is your assessment of the current state of water?

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APPENDIX B

A QUESTIONNAIRE ABOUT GROUNDWATER QUALITY OF URBAN AREA IN THE REGION

Form no ☐

1. Age: ☐

2. Education level: a. Primary ☐ b. Preparatory ☐
   c. Secondary ☐ d. High education ☐

3. Occupation: ……..

4. Monthly income: ☐ LD

5. Kind of house (optional):
   a. villa ☐
   b. public house ☐
   c. apartment ☐

6. The neighborhood where you live: ……..

7. Location of the house:
   a. at the valley ☐
   b. at the plain area ☐
   c. at the slope area ☐

8. The kind of soil in the region: a. red clay soil ☐ b. rocky soil ☐
   c. sediment soil ☐ d. sandy soil ☐ e. others ☐

9. What is the water source that you rely on it?
   a. ground water ☐
   b. desalinated water ☐
   c. both ☐

10. Quality of water in the region: a. fresh ☐ b. salty ☐
    c. d. poor ☐

11. What is the way that uses to get rid of solid waste in your neighborhood?
    a. transport directly in special trucks ☐
    b. put them in open places before transfer process ☐

c. put them in boxes before transfer process ☐

12. How is the final disposal process of solid waste?
    a. in open places ☐
    b. by burning ☐
    c. health and safety landfill ☐

13. Is there overflowing of sewage in the region? a. yes ☐ b. no ☐

14. An available water is valid for:
    a. all human uses ☐
    b. washing and cooking ☐
    c. just washing ☐

15. Have you noticed that there is a change in the water quality in recent years?

a. yes ☐ b. no ☐

16. If yes, this change in:

a. taste ☐
b. smell ☐
c. color ☐
d. all of them ☐

17. Have you noticed that there is a change in the water quantity in recent years?

a. yes ☐ b. no ☐

18. What is the way that used to disposal of sewage in your residential neighborhood?

a. sewage network ☐
b. sewage tank ☐

19. If sewage tank, do you discharge it constantly? a. yes ☐ b. no ☐

20. Is there a station for sewage treatment in your neighborhood?

a. yes ☐ b. no ☐

21. Is there any industrial activities on or nearby your neighborhood?

a. yes ☐ b. no ☐

22. Do the responsible authorities add chlorine to the water?

a. yes ☐ b. no ☐

23. If yes, when? a. Weekly ☐ b. Monthly ☐

c. Annually ☐ d. with necessary ☐

24. Is there processes of chemical and biological analysis to detect the viability of water for human use? a. yes ☐ b. no ☐

25. If yes, when? a. Weekly ☐ b. Monthly ☐

c. Annually ☐ d. other ☐

26. Dose one of your family got disease due to contaminated water?

a. yes ☐ b. no ☐

27. If yes, what this diseases? a. Dermatologist ☐ b. Chest diseases ☐

c. Intestinal diseases ☐ d. Others ☐

28. Have you noticed that there is an increase in the salinity of water in recent years?

a. yes ☐ b. no ☐

29. If yes, do you think that is a result of:

a. seawater intrusion ☐
b. low water level ☐

30. Is there an accumulation of solid waste in the region?

31. Is there a factory for organic fertilizer in the region?

a. yes ☐ b. no ☐

32. What is your assessment of the current state of water in the region?

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APPENDIX C

CLIMATE DATA

Table 1: monthly averages of temperature in the weather stations of Derna (1960-2000) and Al-Ftaih from (1975 – 2000)

Months	1	2	3	4	5	6	7	8	9	10	11	12	Annually average
Derna	14.2	14.5	15.5	17.8	20.4	23.7	25.4	26.1	25.2	22.8	19.2	15.8	20.1
Al-Ftaih	12.3	12.7	13.9	16.8	19.8	23.2	24.9	25.3	24.0	21.3	17.5	14.1	18.8

Table 2: monthly averages of rainfall in the weather stations of Derna and Al-Ftaih from (1960 – 2000)

Months	1	2	3	4	5	6	7	8	9	10	11	12	Annually average
Derna	64.2	39.5	21.5	10.3	4.4	3.4	0.0	0.0	4.2	36.5	27.2	55.1	266.4
Al-Ftaih	73.9	43.4	30.7	11.2	5.5	1.3	0.2	0.1	4.6	28.5	34.9	67.2	301.4

Table 3: monthly averages of humidity in the weather stations of Derna (1960-2000) and Al-Ftaih from (1975 – 2000)

Months	1	2	3	4	5	6	7	8	9	10	11	12	Annually average
Derna	73	70	71	70	72	73	77	76	74	71	70	71	72
Al-Ftaih	74	72	71	63	60	60	68	69	69	67	67	73	68

Table 4: Monthly averages of wind speed (Km/ h) from 1961-200.

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Speed	18	19.7	18.9	17.6	18.9	17.6	21.6	20.7	16.3	14.8	17.2	19.4

APPENDIX D

BACTERIAL AND CHEMICAL ANALYSIS OF WATER

The General Company of Water
The Central Laboratory, Derna, Libya

Bacterial analysis of wells

Well No	Colony bacteria in 100 cm^3		Coliform bacteria	Result
	Mix growth	E.coli		
1	over count	0	-	Not valid for drinking
2	18	100	-	Not valid for drinking
3	over count	23	-	Not valid for drinking
4	over count	7	-	Not valid for drinking
5	9	0	Not found	Valid
6	7	0	Not found	Valid
7	13	0	-	Not valid for drinking
8	23	0	-	Not valid for drinking
9	9	0	-	Valid
10	2	0	Not found	Valid
11	over count	0	Not found	Not valid for drinking
12	over count	100	Not found	Not valid for drinking
13	over count	3	Not found	Not valid for drinking
14	over count	5	-	Not valid for drinking
15	over count	9	-	Not valid for drinking
16	over count	2	Not found	Not valid for drinking
17	45	7	Not found	Not valid for drinking
18	60	23	Not found	Not valid for drinking
19	over count	0	Not found	Not valid for drinking
20	over count	9	Not found	Not valid for drinking
21	over count	11	Not found	Not valid for drinking
22	83	29	Not found	Valid
23	over count	88	Not found	Not valid for drinking
24	over count	0	Not found	Not valid for drinking
25	8	13	Not found	Not valid for drinking
26	13	19		Not valid for drinking
27	over count	0	Not found	Not valid for drinking
28	over count	33	Not found	Not valid for drinking
29	over count	12	Not found	Not valid for drinking

The General Company of Water
The Central Laboratory, Derna, Libya

Chemical analysis

Parameters	PH	EC	TDS	T.H	Ca++	Mg++	Fe	NH4	C1	NO2	PO4
1	7.0	1638	982	400	64	58	0	0	140	0	0
2	7.7	1900	950	380	96	34	0.1	0.2	180	0.2	1
3	7.3	790	640	320	64	64	0	0	160	0	0
4	-	12050	8000	1700	280	243	0	0	1140	0	-
5	6.8	3380	2028	900	186	116	0	0	360	0	0
6	7.0	1570	942	380	88	38	0	0	180	0	0
7	7.4	2950	2183	750	160	92	0	0	260	0	0
8	7.0	1777	1200	560	136	53	0	0	160	0	0
9	7.8	2340	1684	640	112	87	0	0	240	0	0. 5
10	-	-	4000	-	-	-	0	0	-	0	1
11	-	1300	750	340	56	32	0	0	80	0	0
12	-	1933	1300	360	88	34	0.1	0	180	0	-
13	-	4650	3100	300	104	10	0.2	0	300	0	0
14	-	1518	920	550	88	31	0.1	0	120	0	-

All parameters expressed in mg/l except EC in μS/cm pH and pH has no units.

The General Company of Water
The Central Laboratory, Derna, Libya

Bacterial analysis of springs

No	Colony bacteria in 100 cm^3		Coliform bacteria	Result
	Mix growth	E.coli		
1	over count	22	Not found	Not valid for drinking
2	over count	6	Not found	Not valid for drinking

Chemical analysis of springs

Parameters	PH	EC	TDS	T.H
Permissible limit	6.5-9.2	µ S/cm	500-1500 mg/l	100-500 mg/l
Spring of Al-Belad	7.0	1090	700	350
Spring of Abu-Mansour	8.1	780	510	240

All parameters expressed in mg/l except EC in µS/cm pH and pH has no units.

APPENDIX E

STATISTICAL ANALYSIS

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FREQUENCIES VARIABLES=education level
  /ORDER=ANALYSIS.
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Frequencies

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[DataSet1] D:\jumma.sav
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Statistics

education level

N	Valid	427
	Missing	0

education level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.00	6	1.4	1.4	1.4
	3.00	46	10.8	10.8	12.2
	4.00	44	10.3	10.3	22.5
	5.00	331	77.5	77.5	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=neighbourhood /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

neighborhood

N	Valid	427
	Missing	0

neighborhood

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	135	31.6	31.6	31.6
	2.00	85	19.9	19.9	51.5
	3.00	99	23.2	23.2	74.7
	4.00	15	3.5	3.5	78.2
	5.00	93	21.8	21.8	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=home location
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

home location

N	Valid	427
	Missing	0

home location

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	28	6.6	6.6	6.6
	2.00	225	52.7	52.7	59.3
	3.00	174	40.7	40.7	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=water sources
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

water source

N	Valid	427
	Missing	0

water source

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	110	25.8	25.8	25.8
	2.00	313	73.3	73.3	99.1
	3.00	4	.9	.9	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=water quality
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

water quality

N	Valid	427
	Missing	0

water quality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	283	66.3	66.3	66.3
	2.00	46	10.8	10.8	77.0
	3.00	98	23.0	23.0	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=waste way
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

waste way

N	Valid	427
	Missing	0

waste way

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	215	50.4	50.4	50.4
	2.00	87	20.4	20.4	70.7
	3.00	125	29.3	29.3	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=waste final
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

waste final

N	Valid	427
	Missing	0

waste final

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	168	39.3	39.3	39.3
	2.00	179	41.9	41.9	81.3
	3.00	80	18.7	18.7	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=sewage overflowing
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

sewage overflowing

N	Valid	427
	Missing	0

sewage overflowing

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	288	67.4	67.4	67.4
	2.00	139	32.6	32.6	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=water valid
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

water valid

N	Valid	427
	Missing	0

water valid

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	258	60.4	60.4	60.4
	2.00	81	19.0	19.0	79.4
	3.00	88	20.6	20.6	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=quality change
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

water quality change

N	Valid	427
	Missing	0

water quality change

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	288	67.4	67.4	67.4
	2.00	139	32.6	32.6	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=change in
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

change in

N	Valid	292
	Missing	135

change in

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	46	10.8	15.8	15.8
	2.00	134	31.4	45.9	61.6
	3.00	18	4.2	6.2	67.8
	4.00	94	22.0	32.2	100.0
	Total	292	68.4	100.0	
Missing	System	135	31.6		
Total		427	100.0		

```
FREQUENCIES VARIABLES=quantity change
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

water quantity change

N	Valid	427
	Missing	0

water quantity change

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	348	81.5	81.5	81.5
	2.00	79	18.5	18.5	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=sewage way
 /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

sewage way

N	Valid	427
	Missing	0

sewage way

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	126	29.5	29.5	29.5
	2.00	301	70.5	70.5	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=sewage station
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

sewage station

N	Valid	426
	Missing	1

sewage station

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	92	21.5	21.6	21.6
	2.00	334	78.2	78.4	100.0
	Total	426	99.8	100.0	
Missing	System	1	.2		
Total		427	100.0		

```
FREQUENCIES VARIABLES=industrial activity
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

industrial activity

N	Valid	427
	Missing	0

industrial activity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	94	22.0	22.0	22.0
	2.00	333	78.0	78.0	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=chloride add
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

chlorine add

N	Valid	427
	Missing	0

chlorine add

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	276	64.6	64.6	64.6
	2.00	151	35.4	35.4	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=when
   /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

if yes when

N	Valid	282
	Missing	145

if yes when

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	16	3.7	5.7	5.7
	2.00	46	10.8	16.3	22.0
	3.00	19	4.4	6.7	28.7
	4.00	201	47.1	71.3	100.0
	Total	282	66.0	100.0	
Missing	System	145	34.0		
Total		427	100.0		

```
FREQUENCIES VARIABLES=analysis
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

chemi bio analysis

N	Valid	427
	Missing	0

Chemical and biological analysis

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	148	34.7	34.7	34.7
	2.00	279	65.3	65.3	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=when2
 /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

if yes when2

N	Valid	150
	Missing	277

if yes when2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	16	3.7	10.7	10.7
	2.00	52	12.2	34.7	45.3
	3.00	55	12.9	36.7	82.0
	4.00	27	6.3	18.0	100.0
	Total	150	35.1	100.0	
Missing	System	277	64.9		
Total		427	100.0		

```
FREQUENCIES VARIABLES=famildis
  /ORDER=ANALYSIS. p{color:0;font-family:Monospaced;font-size:14pt;font-
style:normal;font-weight:normal;text-decoration:none}
FREQUENCIES VARIABLES=whatdis
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

family disease

N	Valid	427
	Missing	0

family disease

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	117	27.4	27.4	27.4
	2.00	310	72.6	72.6	100.0
	Total	427	100.0	100.0	

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

if yes what disease

N	Valid	117
	Missing	310

if yes what disease

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	13	3.0	11.1	11.1
	2.00	2	.5	1.7	12.8
	3.00	95	22.2	81.2	94.0
	4.00	7	1.6	6.0	100.0
	Total	117	27.4	100.0	
Missing	System	310	72.6		
Total		427	100.0		

```
FREQUENCIES VARIABLES=incsalt
/ORDER=ANALYSIS. p{color:0;font-family:Monospaced;font-size:14pt;font-
style:normal;font-weight:normal;text-decoration:none}
GET   FILE='D:\jumma.sav'. FREQUENCIES VARIABLES=resultof
/ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

increase salt

N	Valid	427
	Missing	0

increase salt

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	150	35.1	35.1	35.1
	2.00	277	64.9	64.9	100.0
	Total	427	100.0	100.0	

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

if yes result of

N	Valid	150
	Missing	277

if yes result of

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	81	19.0	54.0	54.0
	2.00	69	16.2	46.0	100.0
	Total	150	35.1	100.0	
Missing	System	277	64.9		
Total		427	100.0		

```
FREQUENCIES VARIABLES=wasteacc
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

waste accumulation

N	Valid	427
	Missing	0

waste accumulation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	276	64.6	64.6	64.6
	2.00	151	35.4	35.4	100.0
	Total	427	100.0	100.0	

```
FREQUENCIES VARIABLES=factorg
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

factory organic

N	Valid	427
	Missing	0

```
SAVE OUTFILE='D:\jumma.sav'   /COMPRESSED. FREQUENCIES
VARIABLES=tankdisc
 /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet1] D:\jumma.sav
```

Statistics

tank discharge

N	Valid	126
	Missing	301

tank discharge

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1.00	75	17.6	59.5	59.5
	2.00	51	11.9	40.5	100.0
	Total	126	29.5	100.0	
Missing	System	301	70.5		
Total		427	100.0		

```
GET   FILE='D:\jumma.sav'. SAVE OUTFILE='D:\jumma.sav'
  /COMPRESSED.
GET   FILE='D:\SPSS Der\Jumma. sav'.
CROSSTABS
/TABLES=quality change BY sewage overflowing
/FORMAT=AVALUE TABLES
/STATISTICS=CHISQ
/CELLS=COUNT
/COUNT ROUND CELL.
```

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
water quality change * sewage overflowing	427	100.0%	0	.0%	427	100.0%

```
[DataSet1] D:\SPSS Der\Jumma. Sav
```

water quality change * sewage overflowing Crosstabulation

Count

		sewage overflowing		
		1.00	2.00	Total
water quality change	1.00	218	70	288
	2.00	70	69	139
Total		288	139	427

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	27.407[a]	1	.000		
Continuity Correction[b]	26.265	1	.000		
Likelihood Ratio	26.721	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	27.343	1	.000		
N of Valid Cases	427				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 45.25.

b. Computed only for a 2x2 table

```
CROSSTABS
/TABLES=quality change BY waste accumulate
/FORMAT=AVALUE TABLES
/STATISTICS=CHISQ
/CELLS=COUNT EXPECTED
 /COUNT ROUND CELL.
```

Crosstabs

```
[DataSet1] D:\SPSS Der\Jumma. Sav
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
water quality change * waste accumulation	427	100.0%	0	.0%	427	100.0%

water quality change * waste accumulation Crosstabulation

			waste accumulation		
			1.00	2.00	Total
water quality change	1.00	Count	191	97	288
		Expected Count	186.2	101.8	288.0
	2.00	Count	85	54	139
		Expected Count	89.8	49.2	139.0
Total		Count	276	151	427
		Expected Count	276.0	151.0	427.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.096[a]	1	.295		
Continuity Correction[b]	.881	1	.348		
Likelihood Ratio	1.088	1	.297		
Fisher's Exact Test				.331	.174
Linear-by-Linear Association	1.093	1	.296		
N of Valid Cases	427				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 49.15.

b. Computed only for a 2x2 table

```
CROSSTABS
/TABLES=quality change BY pesticides use
/FORMAT=AVALUE TABLES
/STATISTICS=CHISQ
/CELLS=COUNT
/COUNT ROUND CELL.
```

Crosstabs

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Quality change * pesticides use	23	100.0%	0	.0%	23	100.0%

quality change * pesticides use Crosstabulation

Count

		pesticides use		Total
		1.00	2.00	
Quality change	1.00	11	2	13
	2.00	4	6	10
Total		15	8	23

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.960[a]	1	.026		
Continuity Correction[b]	3.188	1	.074		
Likelihood Ratio	5.098	1	.024		
Fisher's Exact Test				.039	.037
Linear-by-Linear Association	4.744	1	.029		
N of Valid Cases	23				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.48.

b. Computed only for a 2x2 table

```
CROSSTABS
 /TABLES=quality change BY agricultural fertilizers use
 /FORMAT=AVALUE TABLES
 /STATISTICS=CHISQ
 /CELLS=COUNT
 /COUNT ROUND CELL.
```

Crosstabs

```
[DataSet1] D:\spss fataih\Alftaih.sav
```

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
quality change * agricultural fertilizers use	23	100.0%	0	.0%	23	100.0%

quality change * agricultural fertilizers use Crosstabulation

Count

		agricultural fertilizers use		
		1.00	2.00	Total
quality,quantity change	1.00	12	2	14
	2.00	3	6	9
Total		15	8	23

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	6.626[a]	1	.010		
Continuity Correction[b]	4.518	1	.034		
Likelihood Ratio	6.780	1	.009		
Fisher's Exact Test				.023	.017
Linear-by-Linear Association	6.338	1	.012		
N of Valid Cases	23				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.13.

b. Computed only for a 2x2 table

```
ONEWAY E.coli BY Section
 /STATISTICS DESCRIPTIVES
 /PLOT MEANS
 /MISSING ANALYSIS
 /POSTHOC=LSD ALPHA (0.05).
```

Oneway

```
[DataSet1] D:\JUMMA RESEARCH\SPSS Der\E.coli data. Sav
```

E.coli count

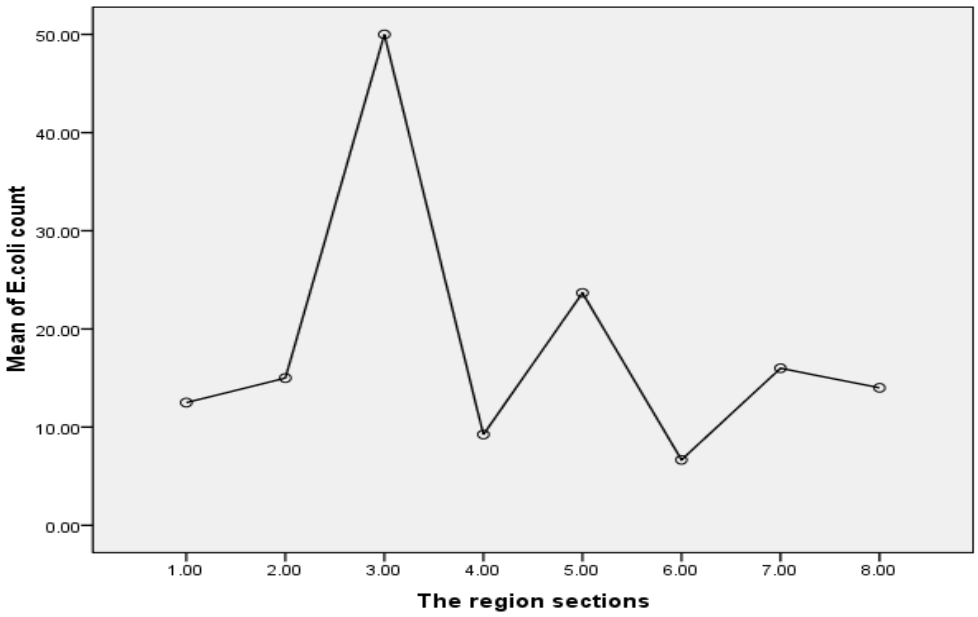
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	8	12.5000	35.35534	12.50000	-17.0578	42.0578	.00	100.00
2.00	2	15.0000	11.31371	8.00000	-86.6496	116.6496	7.00	23.00
3.00	2	50.0000	70.71068	50.00000	-585.3102	685.3102	.00	100.00
4.00	4	9.2500	9.67385	4.83692	-6.1433	24.6433	2.00	23.00
5.00	6	23.6667	33.01919	13.48003	-10.9848	58.3182	.00	88.00
6.00	3	6.6667	6.50641	3.75648	-9.4961	22.8295	.00	13.00
7.00	4	16.0000	13.78405	6.89202	-5.9335	37.9335	.00	33.00
8.00	2	14.0000	11.31371	8.00000	-87.6496	115.6496	6.00	22.00
Total	31	16.8065	28.04095	5.03630	6.5209	27.0920	.00	100.00

ANOVA

E.coli count

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3196.089	7	456.584	.515	.814
Within Groups	20392.750	23	886.641		
Total	23588.839	30			

Means Plots



```
GET   FILE='C:\Users\user\Desktop\TDS  data.sav'. SAVE
OUTFILE='C:\Users\user\Desktop\TDS  data.sav'  /COMPRESSED.
 ONEWAY TDS BY section
 /STATISTICS DESCRIPTIVES
 /PLOT MEANS
 /MISSING ANALYSIS
 /POSTHOC=LSD ALPHA(0.05).
```

Oneway

```
[DataSet1] C:\Users\user\Desktop\TDS  data.sav
```

Descriptives

TDS

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	966.0000	22.62742	16.00000	762.7007	1169.2993	950.00	982.00
2.00	2	4320.0000	5204.30591	3680.00000	-42438.8334	51078.8334	640.00	8000.00
3.00	2	1485.0000	767.91796	543.00000	-5414.4692	8384.4692	942.00	2028.00
4.00	2	1691.5000	695.08597	491.50000	-4553.5996	7936.5996	1200.00	2183.00
5.00	2	2842.0000	1637.65931	1158.00000	-11871.7851	17555.7851	1684.00	4000.00
6.00	2	1925.0000	1661.70094	1175.00000	-13004.7906	16854.7906	750.00	3100.00
7.00	2	605.0000	134.35029	95.00000	-602.0894	1812.0894	510.00	700.00
Total	14	1976.3571	2010.67710	537.37606	815.4267	3137.2875	510.00	8000.00

ANOVA

TDS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.894E7	6	3156218.119	.657	.687
Within Groups	3.362E7	7	4802768.929		
Total	5.256E7	13			

Post Hoc Tests

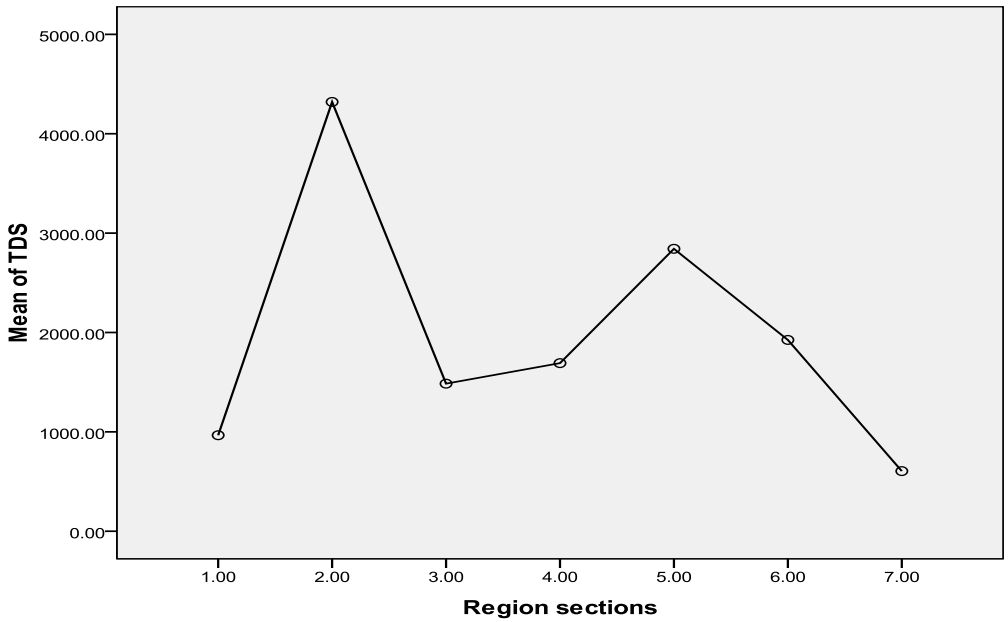
Multiple Comparisons

TDS
LSD

(I) Region sections	(J) Region sections	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-3354.00000	2191.52206	.170	-8536.1262	1828.1262
	3.00	-519.00000	2191.52206	.820	-5701.1262	4663.1262
	4.00	-725.50000	2191.52206	.750	-5907.6262	4456.6262
	5.00	-1876.00000	2191.52206	.420	-7058.1262	3306.1262
	6.00	-959.00000	2191.52206	.675	-6141.1262	4223.1262
	7.00	361.00000	2191.52206	.874	-4821.1262	5543.1262
2.00	1.00	3354.00000	2191.52206	.170	-1828.1262	8536.1262
	3.00	2835.00000	2191.52206	.237	-2347.1262	8017.1262
	4.00	2628.50000	2191.52206	.269	-2553.6262	7810.6262
	5.00	1478.00000	2191.52206	.522	-3704.1262	6660.1262
	6.00	2395.00000	2191.52206	.311	-2787.1262	7577.1262
	7.00	3715.00000	2191.52206	.134	-1467.1262	8897.1262
3.00	1.00	519.00000	2191.52206	.820	-4663.1262	5701.1262
	2.00	-2835.00000	2191.52206	.237	-8017.1262	2347.1262
	4.00	-206.50000	2191.52206	.928	-5388.6262	4975.6262
	5.00	-1357.00000	2191.52206	.555	-6539.1262	3825.1262
	6.00	-440.00000	2191.52206	.847	-5622.1262	4742.1262
	7.00	880.00000	2191.52206	.700	-4302.1262	6062.1262
4.00	1.00	725.50000	2191.52206	.750	-4456.6262	5907.6262
	2.00	-2628.50000	2191.52206	.269	-7810.6262	2553.6262
	3.00	206.50000	2191.52206	.928	-4975.6262	5388.6262
	5.00	-1150.50000	2191.52206	.616	-6332.6262	4031.6262
	6.00	-233.50000	2191.52206	.918	-5415.6262	4948.6262
	7.00	1086.50000	2191.52206	.635	-4095.6262	6268.6262
5.00	1.00	1876.00000	2191.52206	.420	-3306.1262	7058.1262
	2.00	-1478.00000	2191.52206	.522	-6660.1262	3704.1262
	3.00	1357.00000	2191.52206	.555	-3825.1262	6539.1262
	4.00	1150.50000	2191.52206	.616	-4031.6262	6332.6262
	6.00	917.00000	2191.52206	.688	-4265.1262	6099.1262
	7.00	2237.00000	2191.52206	.341	-2945.1262	7419.1262
6.00	1.00	959.00000	2191.52206	.675	-4223.1262	6141.1262
	2.00	-2395.00000	2191.52206	.311	-7577.1262	2787.1262
	3.00	440.00000	2191.52206	.847	-4742.1262	5622.1262

	4.00	233.50000	2191.52206	.918	-4948.6262	5415.6262
	5.00	-917.00000	2191.52206	.688	-6099.1262	4265.1262
	7.00	1320.00000	2191.52206	.566	-3862.1262	6502.1262
7.00	1.00	-361.00000	2191.52206	.874	-5543.1262	4821.1262
	2.00	-3715.00000	2191.52206	.134	-8897.1262	1467.1262
	3.00	-880.00000	2191.52206	.700	-6062.1262	4302.1262
	4.00	-1086.50000	2191.52206	.635	-6268.6262	4095.6262
	5.00	-2237.00000	2191.52206	.341	-7419.1262	2945.1262
	6.00	-1320.00000	2191.52206	.566	-6502.1262	3862.1262

Means Plots

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  /PLOT MEANS
  /MISSING ANALYSIS
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Oneway

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Descriptives

TH

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	390.0000	14.14214	10.00000	262.9380	517.0620	380.00	400.00
2.00	2	1010.0000	975.80736	690.00000	-7757.2813	9777.2813	320.00	1700.00
3.00	2	640.0000	367.69553	260.00000	-2663.6132	3943.6132	380.00	900.00
4.00	2	655.0000	134.35029	95.00000	-552.0894	1862.0894	560.00	750.00
5.00	2	320.0000	452.54834	320.00000	-3745.9855	4385.9855	.00	640.00
6.00	2	445.0000	148.49242	105.00000	-889.1515	1779.1515	340.00	550.00
7.00	2	295.0000	77.78175	55.00000	-403.8413	993.8413	240.00	350.00
Total	14	536.4286	402.54206	107.58389	304.0077	768.8494	.00	1700.00

ANOVA

TH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	767971.429	6	127995.238	.669	.680
Within Groups	1338550.000	7	191221.429		
Total	2106521.429	13			

Post Hoc Tests

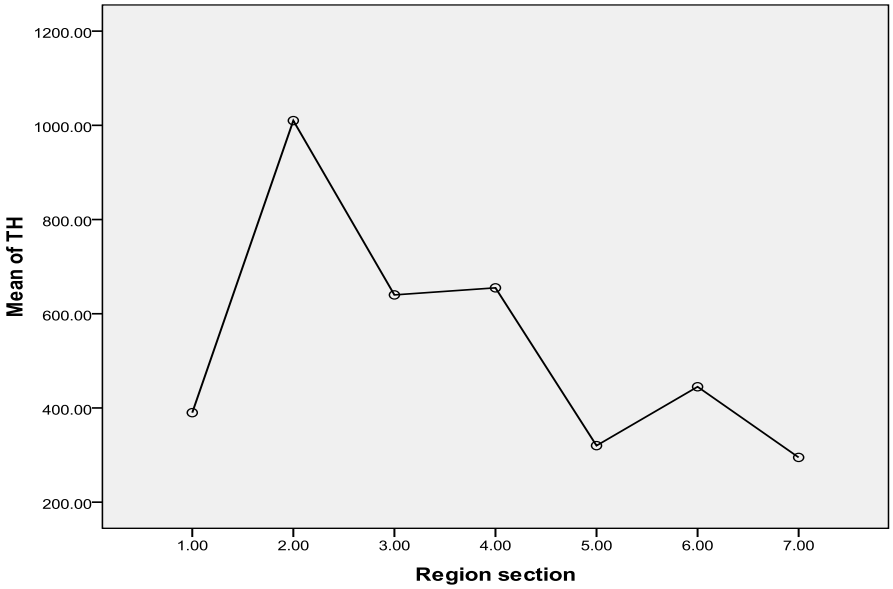
Multiple Comparisons

TH
LSD

(I) Region section	(J) Region section	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-620.00000	437.28872	.199	-1654.0235	414.0235
	3.00	-250.00000	437.28872	.585	-1284.0235	784.0235
	4.00	-265.00000	437.28872	.564	-1299.0235	769.0235
	5.00	70.00000	437.28872	.877	-964.0235	1104.0235
	6.00	-55.00000	437.28872	.903	-1089.0235	979.0235
	7.00	95.00000	437.28872	.834	-939.0235	1129.0235
2.00	1.00	620.00000	437.28872	.199	-414.0235	1654.0235
	3.00	370.00000	437.28872	.425	-664.0235	1404.0235
	4.00	355.00000	437.28872	.444	-679.0235	1389.0235
	5.00	690.00000	437.28872	.159	-344.0235	1724.0235

	6.00	565.00000	437.28872	.237	-469.0235	1599.0235
	7.00	715.00000	437.28872	.146	-319.0235	1749.0235
3.00	1.00	250.00000	437.28872	.585	-784.0235	1284.0235
	2.00	-370.00000	437.28872	.425	-1404.0235	664.0235
	4.00	-15.00000	437.28872	.974	-1049.0235	1019.0235
	5.00	320.00000	437.28872	.488	-714.0235	1354.0235
	6.00	195.00000	437.28872	.669	-839.0235	1229.0235
	7.00	345.00000	437.28872	.456	-689.0235	1379.0235
4.00	1.00	265.00000	437.28872	.564	-769.0235	1299.0235
	2.00	-355.00000	437.28872	.444	-1389.0235	679.0235
	3.00	15.00000	437.28872	.974	-1019.0235	1049.0235
	5.00	335.00000	437.28872	.469	-699.0235	1369.0235
	6.00	210.00000	437.28872	.646	-824.0235	1244.0235
	7.00	360.00000	437.28872	.438	-674.0235	1394.0235
5.00	1.00	-70.00000	437.28872	.877	-1104.0235	964.0235
	2.00	-690.00000	437.28872	.159	-1724.0235	344.0235
	3.00	-320.00000	437.28872	.488	-1354.0235	714.0235
	4.00	-335.00000	437.28872	.469	-1369.0235	699.0235
	6.00	-125.00000	437.28872	.783	-1159.0235	909.0235
	7.00	25.00000	437.28872	.956	-1009.0235	1059.0235
6.00	1.00	55.00000	437.28872	.903	-979.0235	1089.0235
	2.00	-565.00000	437.28872	.237	-1599.0235	469.0235
	3.00	-195.00000	437.28872	.669	-1229.0235	839.0235
	4.00	-210.00000	437.28872	.646	-1244.0235	824.0235
	5.00	125.00000	437.28872	.783	-909.0235	1159.0235
	7.00	150.00000	437.28872	.742	-884.0235	1184.0235
7.00	1.00	-95.00000	437.28872	.834	-1129.0235	939.0235
	2.00	-715.00000	437.28872	.146	-1749.0235	319.0235
	3.00	-345.00000	437.28872	.456	-1379.0235	689.0235
	4.00	-360.00000	437.28872	.438	-1394.0235	674.0235
	5.00	-25.00000	437.28872	.956	-1059.0235	1009.0235
	6.00	-150.00000	437.28872	.742	-1184.0235	884.0235

Means Plots

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Oneway

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[DataSet1] C:\Users\user\Desktop\TDS  data.sav
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Descriptives

EC

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	1769.0000	185.26198	131.00000	104.4872	3433.5128	1638.00	1900.00
2.00	2	6420.0000	7962.02236	5630.00000	-65115.9327	77955.9327	790.00	12050.00
3.00	2	2475.0000	1279.86327	905.00000	-9024.1153	13974.1153	1570.00	3380.00
4.00	2	2363.5000	829.43625	586.50000	-5088.6891	9815.6891	1777.00	2950.00
5.00	2	1170.0000	1654.62987	1170.00000	-13696.2595	16036.2595	.00	2340.00
6.00	2	2975.0000	2368.80772	1675.00000	-18307.8929	24257.8929	1300.00	4650.00
7.00	2	935.0000	219.20310	155.00000	-1034.4617	2904.4617	780.00	1090.00
Total	14	2586.7857	2971.31580	794.11755	871.1990	4302.3724	.00	12050.00

ANOVA
EC

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.062E7	6	6770348.643	.639	.699
Within Groups	7.415E7	7	1.059E7		
Total	1.148E8	13			

Post Hoc Tests

Multiple Comparisons

EC
LSD

(I) Region sections	(J) Region sections	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-4651.00000	3254.69412	.196	-12347.1286	3045.1286
	3.00	-706.00000	3254.69412	.834	-8402.1286	6990.1286
	4.00	-594.50000	3254.69412	.860	-8290.6286	7101.6286
	5.00	599.00000	3254.69412	.859	-7097.1286	8295.1286
	6.00	-1206.00000	3254.69412	.722	-8902.1286	6490.1286
	7.00	834.00000	3254.69412	.805	-6862.1286	8530.1286
2.00	1.00	4651.00000	3254.69412	.196	-3045.1286	12347.1286
	3.00	3945.00000	3254.69412	.265	-3751.1286	11641.1286
	4.00	4056.50000	3254.69412	.253	-3639.6286	11752.6286
	5.00	5250.00000	3254.69412	.151	-2446.1286	12946.1286
	6.00	3445.00000	3254.69412	.325	-4251.1286	11141.1286
	7.00	5485.00000	3254.69412	.136	-2211.1286	13181.1286
3.00	1.00	706.00000	3254.69412	.834	-6990.1286	8402.1286
	2.00	-3945.00000	3254.69412	.265	-11641.1286	3751.1286
	4.00	111.50000	3254.69412	.974	-7584.6286	7807.6286
	5.00	1305.00000	3254.69412	.700	-6391.1286	9001.1286
	6.00	-500.00000	3254.69412	.882	-8196.1286	7196.1286
	7.00	1540.00000	3254.69412	.650	-6156.1286	9236.1286
4.00	1.00	594.50000	3254.69412	.860	-7101.6286	8290.6286
	2.00	-4056.50000	3254.69412	.253	-11752.6286	3639.6286
	3.00	-111.50000	3254.69412	.974	-7807.6286	7584.6286
	5.00	1193.50000	3254.69412	.725	-6502.6286	8889.6286
	6.00	-611.50000	3254.69412	.856	-8307.6286	7084.6286
	7.00	1428.50000	3254.69412	.674	-6267.6286	9124.6286
5.00	1.00	-599.00000	3254.69412	.859	-8295.1286	7097.1286

	2.00	-5250.00000	3254.69412	.151	-12946.1286	2446.1286
	3.00	-1305.00000	3254.69412	.700	-9001.1286	6391.1286
	4.00	-1193.50000	3254.69412	.725	-8889.6286	6502.6286
	6.00	-1805.00000	3254.69412	.596	-9501.1286	5891.1286
	7.00	235.00000	3254.69412	.944	-7461.1286	7931.1286
6.00	1.00	1206.00000	3254.69412	.722	-6490.1286	8902.1286
	2.00	-3445.00000	3254.69412	.325	-11141.1286	4251.1286
	3.00	500.00000	3254.69412	.882	-7196.1286	8196.1286
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	5.00	1805.00000	3254.69412	.596	-5891.1286	9501.1286
	7.00	2040.00000	3254.69412	.551	-5656.1286	9736.1286
7.00	1.00	-834.00000	3254.69412	.805	-8530.1286	6862.1286
	2.00	-5485.00000	3254.69412	.136	-13181.1286	2211.1286
	3.00	-1540.00000	3254.69412	.650	-9236.1286	6156.1286
	4.00	-1428.50000	3254.69412	.674	-9124.6286	6267.6286
	5.00	-235.00000	3254.69412	.944	-7931.1286	7461.1286
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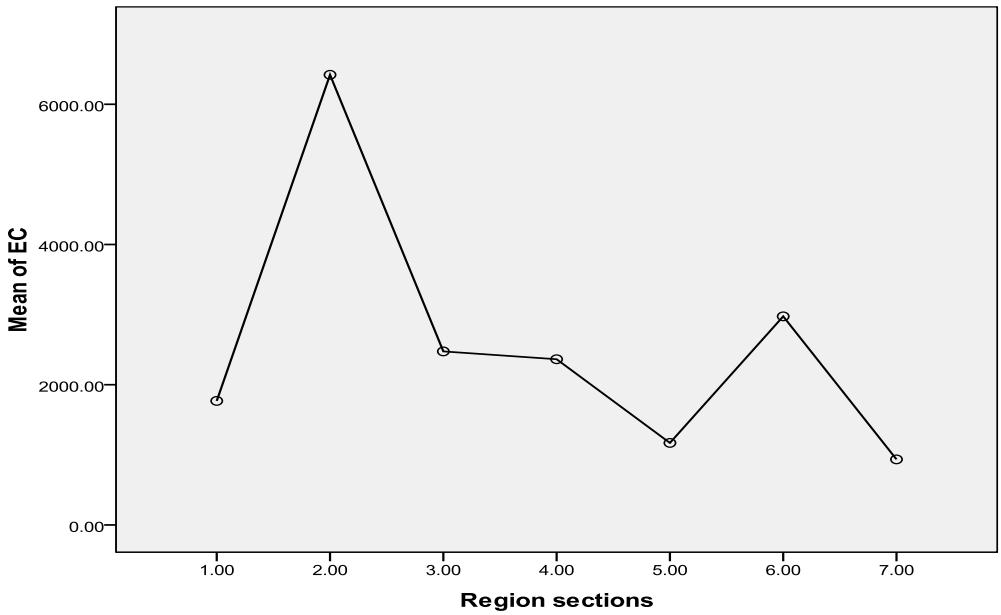
Means Plots

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Oneway

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Descriptives

Ca

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	80.0000	22.62742	16.00000	-123.2993	283.2993	64.00	96.00
2.00	2	172.0000	152.73506	108.00000	-1200.2701	1544.2701	64.00	280.00
3.00	2	137.0000	69.29646	49.00000	-485.6040	759.6040	88.00	186.00
4.00	2	148.0000	16.97056	12.00000	-4.4745	300.4745	136.00	160.00
5.00	2	56.0000	79.19596	56.00000	-655.5475	767.5475	.00	112.00
6.00	2	80.0000	33.94113	24.00000	-224.9489	384.9489	56.00	104.00
Total	12	112.1667	72.46546	20.91898	66.1243	158.2090	.00	280.00

ANOVA

Ca

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21409.667	5	4281.933	.707	.640
Within Groups	36354.000	6	6059.000		
Total	57763.667	11			

Post Hoc Tests

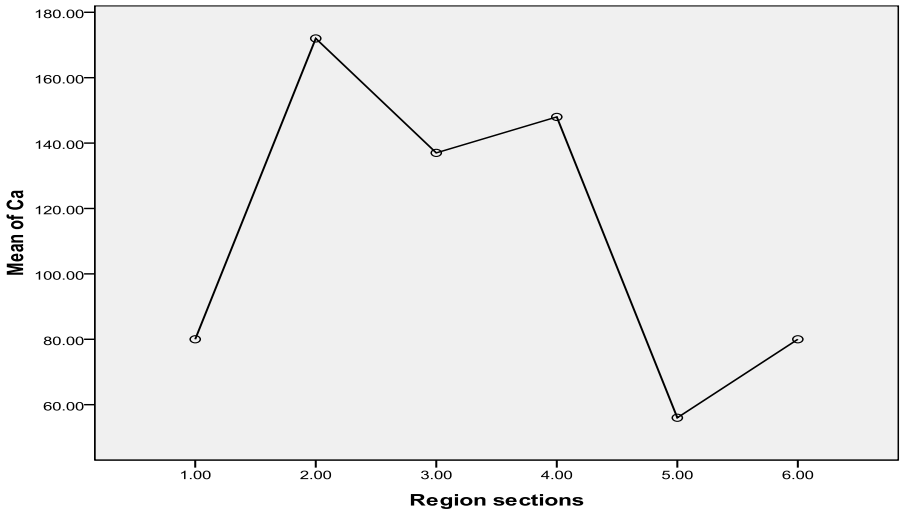
Multiple Comparisons

Ca
LSD

(I) Region sections	(J) Region sections	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-92.00000	77.83958	.282	-282.4666	98.4666
	3.00	-57.00000	77.83958	.492	-247.4666	133.4666
	4.00	-68.00000	77.83958	.416	-258.4666	122.4666
	5.00	24.00000	77.83958	.768	-166.4666	214.4666
	6.00	.00000	77.83958	1.000	-190.4666	190.4666
2.00	1.00	92.00000	77.83958	.282	-98.4666	282.4666
	3.00	35.00000	77.83958	.669	-155.4666	225.4666

	4.00	24.00000	77.83958	.768	-166.4666	214.4666
	5.00	116.00000	77.83958	.187	-74.4666	306.4666
	6.00	92.00000	77.83958	.282	-98.4666	282.4666
3.00	1.00	57.00000	77.83958	.492	-133.4666	247.4666
	2.00	-35.00000	77.83958	.669	-225.4666	155.4666
	4.00	-11.00000	77.83958	.892	-201.4666	179.4666
	5.00	81.00000	77.83958	.338	-109.4666	271.4666
	6.00	57.00000	77.83958	.492	-133.4666	247.4666
4.00	1.00	68.00000	77.83958	.416	-122.4666	258.4666
	2.00	-24.00000	77.83958	.768	-214.4666	166.4666
	3.00	11.00000	77.83958	.892	-179.4666	201.4666
	5.00	92.00000	77.83958	.282	-98.4666	282.4666
	6.00	68.00000	77.83958	.416	-122.4666	258.4666
5.00	1.00	-24.00000	77.83958	.768	-214.4666	166.4666
	2.00	-116.00000	77.83958	.187	-306.4666	74.4666
	3.00	-81.00000	77.83958	.338	-271.4666	109.4666
	4.00	-92.00000	77.83958	.282	-282.4666	98.4666
	6.00	-24.00000	77.83958	.768	-214.4666	166.4666
6.00	1.00	.00000	77.83958	1.000	-190.4666	190.4666
	2.00	-92.00000	77.83958	.282	-282.4666	98.4666
	3.00	-57.00000	77.83958	.492	-247.4666	133.4666
	4.00	-68.00000	77.83958	.416	-258.4666	122.4666
	5.00	24.00000	77.83958	.768	-166.4666	214.4666

Means Plots

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Oneway

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Descriptives

Ma

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	46.0000	16.97056	12.00000	-106.4745	198.4745	34.00	58.00
2.00	2	153.5000	126.57211	89.50000	-983.7053	1290.7053	64.00	243.00
3.00	2	77.0000	55.15433	39.00000	-418.5420	572.5420	38.00	116.00
4.00	2	72.5000	27.57716	19.50000	-175.2710	320.2710	53.00	92.00
5.00	2	43.5000	61.51829	43.50000	-509.2199	596.2199	.00	87.00
6.00	2	21.0000	15.55635	11.00000	-118.7683	160.7683	10.00	32.00
Total	12	68.9167	64.34065	18.57355	28.0366	109.7968	.00	243.00

ANOVA

Ma

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21399.417	5	4279.883	1.064	.462
Within Groups	24137.500	6	4022.917		
Total	45536.917	11			

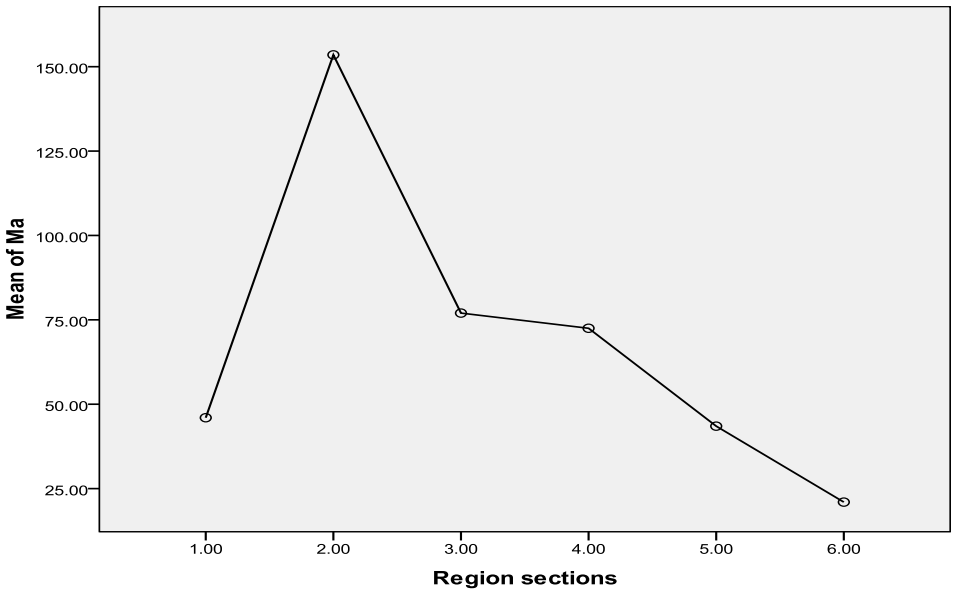
Post Hoc Tests

Multiple Comparisons

Ma
LSD

(I) Region sections	(J) Region sections	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-107.50000	63.42647	.141	-262.6990	47.6990
	3.00	-31.00000	63.42647	.642	-186.1990	124.1990
	4.00	-26.50000	63.42647	.691	-181.6990	128.6990
	5.00	2.50000	63.42647	.970	-152.6990	157.6990
	6.00	25.00000	63.42647	.707	-130.1990	180.1990
2.00	1.00	107.50000	63.42647	.141	-47.6990	262.6990
	3.00	76.50000	63.42647	.273	-78.6990	231.6990
	4.00	81.00000	63.42647	.249	-74.1990	236.1990
	5.00	110.00000	63.42647	.134	-45.1990	265.1990
	6.00	132.50000	63.42647	.082	-22.6990	287.6990
3.00	1.00	31.00000	63.42647	.642	-124.1990	186.1990
	2.00	-76.50000	63.42647	.273	-231.6990	78.6990
	4.00	4.50000	63.42647	.946	-150.6990	159.6990
	5.00	33.50000	63.42647	.616	-121.6990	188.6990
	6.00	56.00000	63.42647	.411	-99.1990	211.1990
4.00	1.00	26.50000	63.42647	.691	-128.6990	181.6990
	2.00	-81.00000	63.42647	.249	-236.1990	74.1990
	3.00	-4.50000	63.42647	.946	-159.6990	150.6990
	5.00	29.00000	63.42647	.664	-126.1990	184.1990
	6.00	51.50000	63.42647	.448	-103.6990	206.6990
5.00	1.00	-2.50000	63.42647	.970	-157.6990	152.6990
	2.00	-110.00000	63.42647	.134	-265.1990	45.1990
	3.00	-33.50000	63.42647	.616	-188.6990	121.6990
	4.00	-29.00000	63.42647	.664	-184.1990	126.1990
	6.00	22.50000	63.42647	.735	-132.6990	177.6990
6.00	1.00	-25.00000	63.42647	.707	-180.1990	130.1990
	2.00	-132.50000	63.42647	.082	-287.6990	22.6990
	3.00	-56.00000	63.42647	.411	-211.1990	99.1990
	4.00	-51.50000	63.42647	.448	-206.6990	103.6990
	5.00	-22.50000	63.42647	.735	-177.6990	132.6990

Means Plots




```
GET   FILE='C:\Users\user\Desktop\Cl data.sav'. SAVE
OUTFILE='C:\Users\user\Desktop\Cl data.sav'
 /COMPRESSED. ONEWAY Cl BY section
 /STATISTICS DESCRIPTIVES
 /PLOT MEANS
 /MISSING ANALYSIS
 /POSTHOC=LSD ALPHA(0.05).
```

Oneway

```
[DataSet1] C:\Users\user\Desktop\Cl data.sav
```

Descriptives

Cl

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	160.0000	28.28427	20.00000	-94.1241	414.1241	140.00	180.00
2.00	2	650.0000	692.96465	490.00000	-5576.0403	6876.0403	160.00	1140.00
3.00	2	270.0000	127.27922	90.00000	-873.5584	1413.5584	180.00	360.00
4.00	2	210.0000	70.71068	50.00000	-425.3102	845.3102	160.00	260.00

5.00	2	120.0000	169.70563	120.00000	-1404.7446	1644.7446	.00	240.00
6.00	2	190.0000	155.56349	110.00000	-1207.6825	1587.6825	80.00	300.00
Total	12	266.6667	291.24602	84.07548	81.6178	451.7156	.00	1140.00

ANOVA

Cl

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	377866.667	5	75573.333	.817	.579
Within Groups	555200.000	6	92533.333		
Total	933066.667	11			

Post Hoc Tests

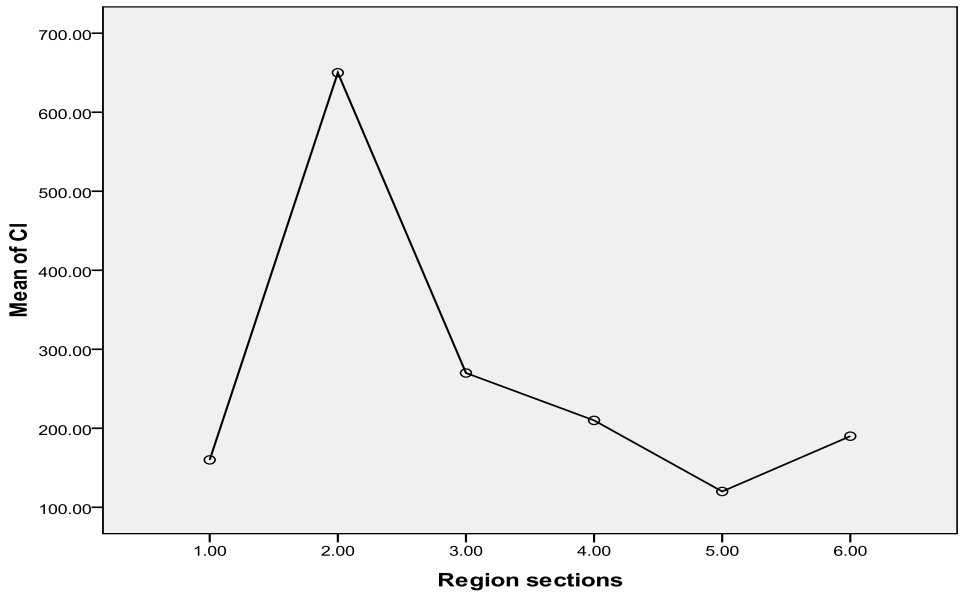
Multiple Comparisons

Cl
LSD

(I) Regionsections	(J) Regionsections	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-490.00000	304.19292	.158	-1234.3333	254.3333
	3.00	-110.00000	304.19292	.730	-854.3333	634.3333
	4.00	-50.00000	304.19292	.875	-794.3333	694.3333
	5.00	40.00000	304.19292	.900	-704.3333	784.3333
	6.00	-30.00000	304.19292	.925	-774.3333	714.3333
2.00	1.00	490.00000	304.19292	.158	-254.3333	1234.3333
	3.00	380.00000	304.19292	.258	-364.3333	1124.3333
	4.00	440.00000	304.19292	.198	-304.3333	1184.3333
	5.00	530.00000	304.19292	.132	-214.3333	1274.3333
	6.00	460.00000	304.19292	.181	-284.3333	1204.3333
3.00	1.00	110.00000	304.19292	.730	-634.3333	854.3333
	2.00	-380.00000	304.19292	.258	-1124.3333	364.3333
	4.00	60.00000	304.19292	.850	-684.3333	804.3333
	5.00	150.00000	304.19292	.639	-594.3333	894.3333
	6.00	80.00000	304.19292	.801	-664.3333	824.3333
4.00	1.00	50.00000	304.19292	.875	-694.3333	794.3333
	2.00	-440.00000	304.19292	.198	-1184.3333	304.3333
	3.00	-60.00000	304.19292	.850	-804.3333	684.3333

	5.00	90.00000	304.19292	.777	-654.3333	834.3333
	6.00	20.00000	304.19292	.950	-724.3333	764.3333
5.00	1.00	-40.00000	304.19292	.900	-784.3333	704.3333
	2.00	-530.00000	304.19292	.132	-1274.3333	214.3333
	3.00	-150.00000	304.19292	.639	-894.3333	594.3333
	4.00	-90.00000	304.19292	.777	-834.3333	654.3333
	6.00	-70.00000	304.19292	.826	-814.3333	674.3333
6.00	1.00	30.00000	304.19292	.925	-714.3333	774.3333
	2.00	-460.00000	304.19292	.181	-1204.3333	284.3333
	3.00	-80.00000	304.19292	.801	-824.3333	664.3333
	4.00	-20.00000	304.19292	.950	-764.3333	724.3333
	5.00	70.00000	304.19292	.826	-674.3333	814.3333

Means Plots




```
SAVE OUTFILE='C: \Users\user\Desktop\sPSS WQI NEW. Sav'
 /COMPRESSED.
REGRESSION
 /DESCRIPTIVES MEAN STDDEV CORR SIG N
 /MISSING LISTWISE
 /STATISTICS COEFF OUTS R ANOVA
 /CRITERIA=PIN (.05) POUT (.10)
 /NOORIGIN   /DEPENDENT WQI
```

```
 /METHOD=ENTER PH TDS TH Ca Mg Fe Cl PO4 E.coli
 /RESIDUALS HIST (ZRESID) NORM (ZRESID).
```

Regression

```
[DataSet0] C:\Users\user\Desktop\sPSS WQI NEW. Sav
```

Descriptive Statistics

	Mean	Std. Deviation	N
WQI	83.6500	28.29431	14
PH	4.1429	3.73275	14
TDS	2048.5000	1966.60358	14
TH	541.4286	399.09238	14
Ca++	108.7143	67.23372	14
Mg++	63.7143	60.64706	14
Fe	.0357	.06333	14
Cl	250.0000	271.49161	14
PO4	.1500	.36109	14
E.coli	16.2143	26.46094	14

Correlations

		WQI	PH	TDS	TH	Ca++	Mg++	Fe	Cl	PO4	E.coli
Pearson Correlation	WQI	1.000	-.023	-.066	.347	.366	.307	-.143	.245	-.937	-.602
	PH	-.023	1.000	-.439	-.005	.073	.076	-.423	-.178	-.013	.184
	TDS	-.066	-.439	1.000	.663	.604	.682	-.054	.830	.088	-.193
	TH	.347	-.005	.663	1.000	.956	.963	-.249	.921	-.370	-.204
	Ca++	.366	.073	.604	.956	1.000	.892	-.115	.886	-.384	-.091
	Mg++	.307	.076	.682	.963	.892	1.000	-.400	.915	-.320	-.286
	Fe	-.143	-.423	-.054	-.249	-.115	-.400	1.000	-.076	.084	.445
	Cl	.245	-.178	.830	.921	.886	.915	-.076	1.000	-.252	-.158
	PO4	-.937	-.013	.088	-.370	-.384	-.320	.084	-.252	1.000	.598
	E.coli	-.602	.184	-.193	-.204	-.091	-.286	.445	-.158	.598	1.000
Sig. (1-tailed)	WQI	.	.469	.411	.112	.099	.143	.313	.199	.000	.011
	PH	.469	.	.058	.493	.402	.398	.066	.272	.483	.264
	TDS	.411	.058	.	.005	.011	.004	.427	.000	.382	.254
	TH	.112	.493	.005	.	.000	.000	.196	.000	.096	.242
	Ca++	.099	.402	.011	.000	.	.000	.348	.000	.088	.379
	Mg++	.143	.398	.004	.000	.000	.	.078	.000	.132	.161
	Fe	.313	.066	.427	.196	.348	.078	.	.398	.388	.055
	Cl	.199	.272	.000	.000	.000	.000	.398	.	.193	.295
	PO4	.000	.483	.382	.096	.088	.132	.388	.193	.	.012
	E.coli	.011	.264	.254	.242	.379	.161	.055	.295	.012	.
N	WQI	14	14	14	14	14	14	14	14	14	14
	PH	14	14	14	14	14	14	14	14	14	14
	TDS	14	14	14	14	14	14	14	14	14	14
	TH	14	14	14	14	14	14	14	14	14	14
	Ca++	14	14	14	14	14	14	14	14	14	14
	Mg++	14	14	14	14	14	14	14	14	14	14
	Fe	14	14	14	14	14	14	14	14	14	14
	Cl	14	14	14	14	14	14	14	14	14	14
	PO4	14	14	14	14	14	14	14	14	14	14
	E.coli	14	14	14	14	14	14	14	14	14	14

Variables Entered/Removed

Model	Variables Entered	Variables Removed	Method
1	E.coli, Ca++, PH, Fe, PO4, TDS, Mg++, Cl, TH[a]	.	Enter

a. All requested variables entered.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.956[a]	.914	.719	14.99694

a. Predictors: (Constant), E.coli, Ca++, PH, Fe, PO4, TDS, Mg++, Cl, TH

b. Dependent Variable: WQI

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	9507.748	9	1056.416	4.697	.075[a]
	Residual	899.633	4	224.908		
	Total	10407.381	13			

a. Predictors: (Constant), E.coli, Ca++, PH, Fe, PO4, TDS, Mg++, Cl, TH

b. Dependent Variable: WQI

Coefficients[a]

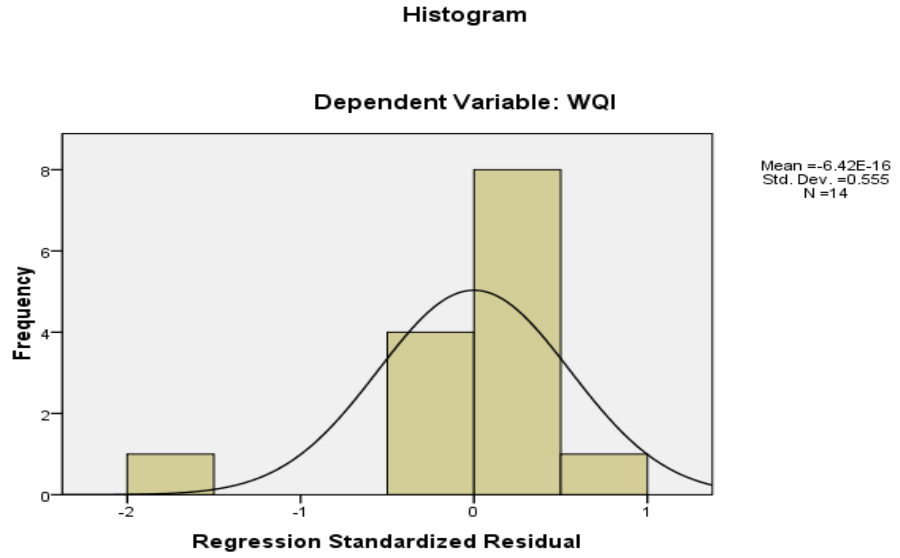
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	108.351	16.794		6.452	.003
	PH	-1.855	2.458	-.245	-.755	.492
	TDS	-.007	.009	-.452	-.756	.492
	TH	-.047	.087	-.665	-.540	.618
	Ca++	.286	.332	.681	.863	.437
	Mg++	-.186	.614	-.398	-.302	.778
	Fe	-152.587	149.149	-.342	-1.023	.364
	Cl	.075	.110	.721	.683	.532
	PO4	-56.464	31.506	-.721	-1.792	.148
	E.coli	-.145	.399	-.135	-.363	.735

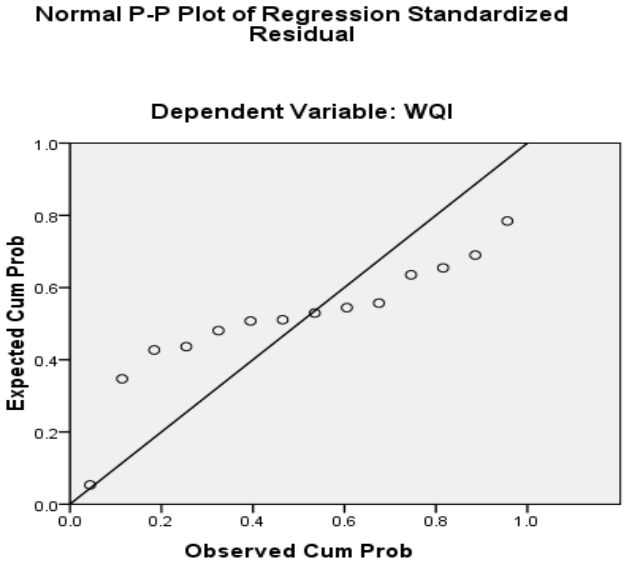
a. Dependent Variable: WQI

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	18.4857	102.5685	83.6500	27.04377	14
Residual	-24.19642	11.79178	.00000	8.31881	14
Std. Predicted Value	-2.410	.700	.000	1.000	14
Std. Residual	-1.613	.786	.000	.555	14

a. Dependent Variable: WQI


Histogram
Dependent Variable: WQI
Mean =-6.42E-16
Std. Dev. =0.555
N =14
Frequency
Regression Standardized Residual


Normal P-P Plot of Regression Standardized Residual
Dependent Variable: WQI
Expected Cum Prob
Observed Cum Prob